RESEARCH ON DIAMOND

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RESEARCH ON THE ABRADING, GRINDING OR POLISHING OF DIAMOND

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1. INTRODUCTION

In the survey of the history of diamond-grinding, and generally of all the processes used in fashioning diamonds, perhaps the most remarkable fact is that so old an art should have progressed entirely by trial and error, by gradual correction and slow progress, by the almost accidental elimination of faults and introduction of ameliorations. It is highly probable that the art of grinding diamonds was known in India two thousand years ago. In Europe, the earliest recorded diamond manufactory existed as far back as 1375, when the polishers had already attained a high degree of guild organisation, and there is every reason to believe that the process of diamond grinding was known centuries before.

All these centuries, when numerous keen minds were directed upon the fashioning of the gem, have left no single record of any

systematic study of the grinding of the diamond. Even now, when the number of books written on diamonds increases rapidly, the authors are dumb upon the subject or rest content, in the most thorough works, with describing superficially the methods actually in use. Nowhere has the writer seen or heard of any critical examination of these methods.

And yet such an enquiry would be very important and interesting both from the scientific and from the industrial point of view.

From the scientific point of view, the diamond, besides having exceptionally great indices of refraction and of dispersion (to which it owes the lively play of light within it, and its consequent attraction as a gem-stone) is also the hardest substance known: it has been taken as the standard of maximum hardness on Mohs' scale, where it has been given 10 as hardness number. Its hardness however is not constant; it is different in planes at different inclinations to the axes of crystallization, and in those planes, it varies with the varying directions

considered; so that a certain edge of diamond may scratch another diamond on one surface, and not on another; or it may scratch a surface in one direction, and not in another.

From the industrial point of view, the great hardness of the diamond makes it a very good cutting tool, and it is frequently used on the faces of rock-drills and also in lathes. Glass is commonly scratched and cut with a diamond tool. But by far the greatest part of the total production of diamonds is sawn, split, cut, and ground or polished into gem-stones. How important the manufacture of these stones (mostly brilliants) is, may be gauged from the fact that the total yearly world output is estimated at upwards of ten million pounds, and that approximately thirty-five thousand grinders or polishers are employed in this industry. As has been stated above, the methods employed by these workmen are almost entirely empirical. It is the purpose of the present thesis to examine them systematically and to determine where and how they may be improved.

The general aim of the present research

from the industrial point of view is to find methods by which the grinding of diamonds can be accelerated: that it would be of very great practical importance if this could be achieved to any large extent cannot be doubted. For in the manufacture of polished diamonds nearly the whole of the time is taken up by grinding processes (for we may reckon sawing as a grinding process) and the time taken by the other processes is negligible in comparison: if a single stone, say, were manufactured as fast as possible, it could be split (—if necessary—) in a few minutes and cut (or rounded) in half an hour to an hour, but the sawing would take two or three days and the grinding and polishing two weeks or more. It is thus plain that any important shortening of the time taken by the grinding processes would shorten the manufacturing time in an almost identical proportion, and correspondingly increase the output of the factory and the turnover of the capital invested in the manufactured diamonds. It needs no proof that these consequences are of the utmost practical importance.

2. VARIABLES

The following are the variables which we have to take into consideration:

Rate of grinding (i. e. speed at which the diamond is ground away).

Speed of grinding wheel.

Radius of track (i. e. of circle on which grinding takes place, and which is formed by the track of the diamond upon the grinding wheel).

Load upon diamond.

Area of diamond in contact with the grinding wheel.

Position of surface ground, relatively to the axes of crystallization.

Direction of grinding on that surface.

3. DESCRIPTION OF MACHINERY USED

From the very beginning of this research it was suspected (and provisional experiments seemed to show) that, as the speed of the grinding wheel increases, the rate of grinding also increases. It was considered of the greatest importance to confirm this experimentally and it was therefore decided to work up to the highest possible speeds. In the experiments speeds up to about 9500 revolutions per minute were used.

Because of the possibility of accidents, owing to the high speeds worked at, work was stopped in one wing of the factory, the wing being selected on the ground floor, to avoid vibration as much as possible, and one of the grinding mills fitted up for the experiments.

TRANSMISSION

The machinery erected was as shown in the general arrangement. (FIG. 1.)

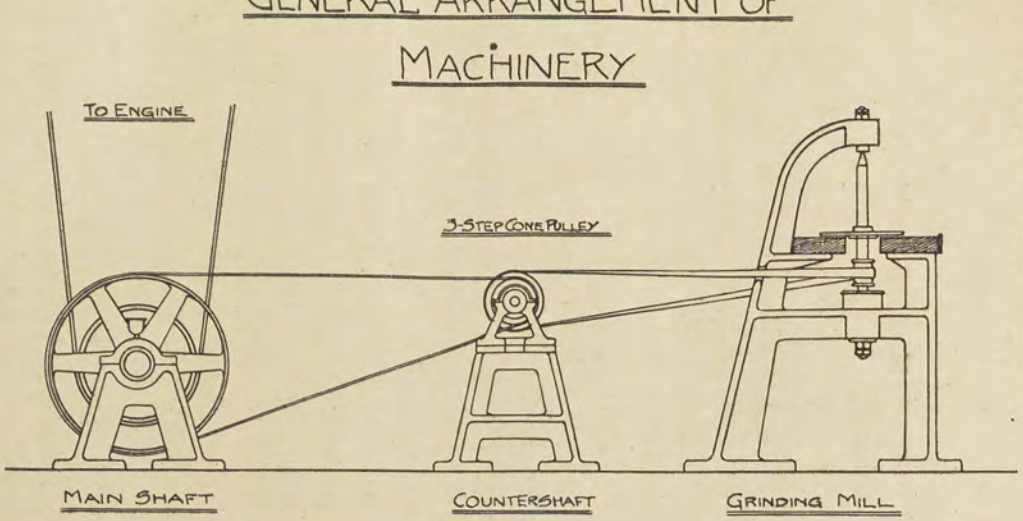

GENERAL ARRANGEMENT OF
MACHINERY
TO ENGINE
3-STEP CONE PULLEY
MAIN SHAFT
COUNTERSHAFT
GRINDING MILL

FIGURE 1

The power is led by belting to the main shaft from which, in the usual course, the cast iron grinding wheels are directly driven by belting. In the present instance, a counter-shaft with a pulley and a 3-step cone was placed between the main-shaft and the mill. This gave 5 possible different speeds for the grinding mill without alteration of the speed of the grinding shaft: for, as the cone pulley was chosen small, it could be used not only as driven, but also as driving pulley without the belt falling off the pulley on the grinding wheel: this arrangement necessitated a high speed of rotation for the counter-shaft; to prevent overheating of the bearings, which was thought likely with the available white-metal bearings, ball bearings were fitted and the plummer blocks bolted to very high pedestals; to ensure that there should be as little vibration as possible, the pedestals were held down by foundation bolts cemented in the concrete floor. The following are the diameters of the pulleys used (including the thickness of the belts):

Main shaft: $2'—2^1/_4'' = 26^1/_4'' = 105/4''$
Countershaft:
3-Step Cone $8^1/_4''$, $6''$, $4''$, i. e. resp. $33/4''$, $24/4''$, $16/4''$,
Pulley $8^1/_4'' = 33/4''$
Grinding wheel: $2^1/_4'' = 9/4''$

This gave the following possible combinations and speeds, the distributing shaft running at about double its usual speed, i. e. at 400 revolutions per minute.

A. 3-step cone is driver, and pulley is driven
speed of countershaft $400 \times 105/33 = 1273$ R.P.M.
1st. speed of grind. wheel $1273 \times 16/9 = 2260$ R.P.M.
2nd. speed „ „ „ $1273 \times 24/9 = 3250$ R.P.M.
3rd. speed „ „ „ $1276 \times 33/9 = 4650$ R.P.M.

B. Pulley is driver, and 3-step cone is driven
4 the speed of grinding wheel: belt from distributing shaft on middle step:
Speed of countershaft $400 \times 105/24 = 1750$ R.P.M.
Speed of grinding wheel $1750 \times 33/9 = 6410$ R.P.M.
5 the speed of grinding wheel: belt from distributing shaft on smallest step of cone:
Speed of countershaft $400 \times 105/16 = 2625$ R.P.M.
Speed of grinding wheel $2625 \times 33/9 = 9640$ R.P.M.

The five speeds of the grinding wheel are thus:

2260 R.P.M.	2150 R.P.M.	being the actual
3250 R.P.M.	3150 R.P.M.	being the actual
4650 R.P.M.	4500 R.P.M.	speed owing
6410 R.P.M.	6250 R.P.M.	to slip, creep, etc.
9640 R.P.M.	9420 R.P.M.	

The speed of 2150 R.P.M. is approximately the rate at which the grinding wheels are

revolving in the actual practice, and 9420 R.P.M. is the highest speed with which trials were made, for it was considered unsafe to attempt a higher rate, owing to the stress in the cast iron grinding wheel created by the centrifugal force approaching the breaking stress. For if we take Grossman's solution of the rotating disc problem, we find:

$$p_y \text{ (max.)} = \frac{w}{g} \times \frac{\omega^2}{4m} \times [(3m+1)\ R_1^2 + (m-1)\ R^2_2] \quad (1)$$

and

$$p_x \text{ (max.)} = \frac{w}{g} \times \frac{\omega^2}{8m} \times (3m+1)\ (R_1 - R_2)^2 \quad (2)$$

where p_y = circumferential or hoop stress;
p_x = radial stress
w = density of material
ω = angular velocity of rotation
$1/m$ = Poisson's ratio
R_1 = external radius of disc
R_2 = internal radius of disc (i. e. radius of hole)

It is obvious from a study of the equations (1) and (2) that the maximum hoop stress is greater than the maximum radial stress. In calculating the breaking speed we will therefore only have to consider equation (1). This equation can be written as follows:

$$\omega^2 = \frac{4 \times p_y \text{ (max.)} \times g \times m}{w\ [(3m+1)\ R_1^2 + (m-1)\ R^2_2]}$$

The following are the values to be substituted for the symbols in the case of the

cast iron grinding wheel as used in diamond grinding. Owing to the porosity of the cast iron used, its ultimate strength is taken as 14 000 lb. per square inch:

$$m = 3$$
$$w = 0{,}260 \text{ lb. per cubic inch}$$
$$R_1 = 6''$$
$$R_2 = {}^5/_8'' = 0.625''$$
$$p_y \text{ (max.)} = 14\,000 \text{ lb. per square inch}$$

$$\omega^2 = \frac{4 \times 14000 \times 32.2 \times 12 \times 3}{0.260\ (10 \times 36 + 2 \times 0.390)} = 69100$$

$$\omega = 265$$

$$N = \frac{265 \times 180}{\pi} = 15\,000 \text{ R. P. M.} = \text{Breaking speed}$$

with a factor of safety of 2, N becomes

$$N = \frac{15\,000}{\sqrt{2}} = 10\,600 \text{ R.P.M.}$$

Grossman's solutions suppose that the material is an elastic one. Cast iron not being perfectly elastic, the values obtained cannot be taken as absolutely correct; they are however not far wrong.

The maximum speed worked at is 9420 R.P.M., which approaches to the above 10 600 R.P.M. Now a factor of safety of 2 is very small, being far below the factor of safety used in engineering practice: It is to be born in mind that the presence of

flaws or cavities is not at all unlikely in this porous cast iron. Moreover the diamond to be ground is applied with pressure on the face of the wheel; this causes each part of the wheel to be subject, once at least per revolution, to that pressure (if only one stone is ground at a time). This creates a bending stress, which although not large in amount is fluctuating very rapidly from a minimum to a maximum and which, superimposed on the hoop stress, will reduce appreciable the actual factor of safety. This factor will be still further reduced if the casting is not absolutely sound. Finally, the central part of the grinding wheel is generally turned out: another source of weakness, which was however avoided in later experiments by turning the working part of the grinding disc down to the same thickness as the central part.

For all the above reasons it was decided that the speed of 9420 R.P.M. could be considered as the limit for all practical purposes, and that it was unnecessary and unadvisable to experiment with greater speeds.

BEARINGS

Great difficulties were experienced as soon as it was attempted to increase the speed of the grinding wheel above the rate usual in present-day factories, and several types of bearings had to be tried before finally a satisfactory one was found. The universal actual practice in diamond grinding mills is to have the spindle of the grinding wheel conical at each end, the point of each cone resting in a small hole made in a wooden block fixed firmly to the casting of the mill. The wood used in these blocks is pockwood (*guajacum*); it is very hard and at the same time rich in fats and it absorbs oil easily: this makes lubrication easy. It was at first attempted to increase the speed of the wheel, using his type of bearing; but at a speed of about 3500 R.P.M. the bottom pockwood started burning and the wheel threatened to leave its bearings.

BALL BEARING AND SEATING

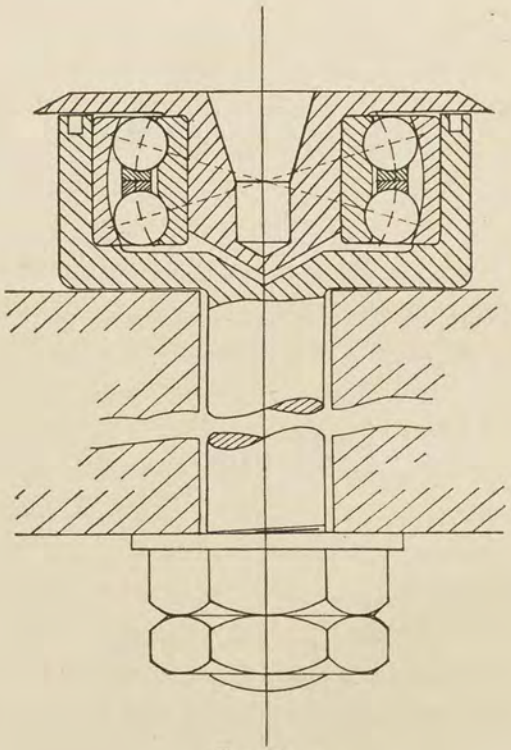


FIGURE 2

In the next attempt, ball bearings were substituted for the bottom pockwood. They were fixed and housed as shown in drawing (FIG. 2). They are of the self-aligning radial type and were chosen specially broad to resist the thrust of the weight of the wheel (etc.) as well as the radial pull of the belt. The outer race is held in a cup bolted firmly down in the place of the bottom pockwood. On the inner race a sleeve fitted with a plate (as shown in drawing) fits tightly. The conical point of the spindle rests in the similarly shaped hole in the sleeve, and the plate passes with a small clearance over the edge of the cup. This plate was found to protect the races and the balls very efficiently from diamond dust, as a strong current of air was continually blowing away all impurity. The ball bearings proved unsatisfactory over about 4000 R.P.M. as they became then very noisy and subjected the grinding mill to excessive vibration. It was found that a mill of the type as shown in general arrangement had to be used, where the bearings are fixed directly to the cast

iron stand. And even then the ball bearings would not permit vibration less running at speeds above 5000 R.P.M. This type of bearing was thus abandoned.

The final type (drawing „Bearings" FIG. 3) is, I think, an entirely novel type of bearing, which proved very successful and was used up to the highest speeds, with no more vibration than with pockwood at 2200 R.P.M. In this type, the point of the spindle revolve in small pieces of fiberine (a red fibrous rubber compound frequently used for thrust washers) or also of pockwood. These are fixed at the end of a long bolt held firmly to the grinding mill by nuts und lock-nuts. Through the bolt and the fiberine — (or the pockwood) — a hole is pierced, and the bearing surface of the fiberine is grooved with three or four radial grooves. The lubricant, which serves at the same time as coolant, flows through tubing from a high pressure container to the bolt and through it to be bearing surface. Owing to the high speed of rotation of the spindle and to its conical shape, the lubricant then

BEARINGS

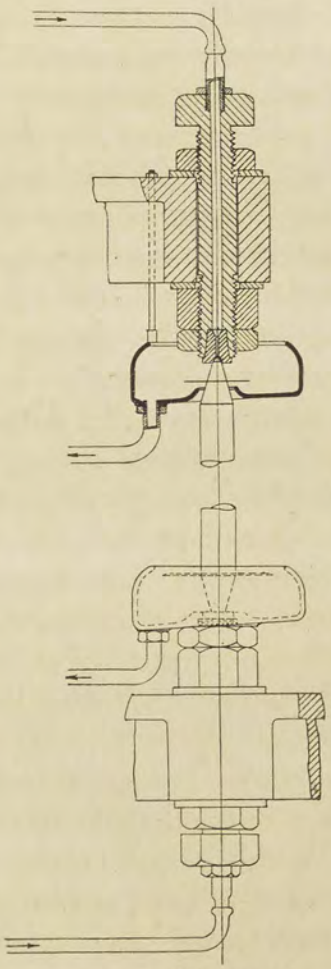


FIGURE 3

tends to flow towards the base of the cone, which it would leave more or less radially owing to the centrifugal force. To prevent its falling on the grinding wheel from the top bearing or its spraying and injuring, the belt from the bottom bearing, small circular discs are fitted some way up the conical part, from which all the lubricant is projected into receivers. It now passes through tubing to the low-pressure container, where it is collected. It was found that with a circulation of 2 gallons per day for the bottom bearing and $^1/_2$ gallon for the top bearing the working surfaces remained cold to the touch even after several hours running at the highest speed.

MACHINE USED FOR DETERMINING SPEED AND ANGLE OF CUT

A special holder was designed in which the diamond could be held so that all the variables could be derived from readings on graduated scales. It was made with the utmost care so that all readings can be taken as correct

to a hight degree of accuracy. It works as follows (see drawing and photographs Figs 4, 5, 6).

A rigid horizontal arm *A* is clamped to a cast iron stand *B* (also very rigid) which is screwed or bolted firmly to the bench of the grinding mill, so that when seen in plan, the axis of the arm lies on a radius of the grinding wheel. At the end of the arm a hole is bored, at the centre of which spindle *C* is free to slide up or down. The actual holder is fixed to the bottom end of that spindle. Between the spindle *C* and the arm *A* two sleeves *D* and *E* are fitted in the hole. The inner sleeve *E* carries the male thread of a micrometer, its upper end, shaped tapering, is divided to read thousands of an inch; these divisions correspond with others engraved on the upper part of spindle *C*. The top of sleeve *E* is the stop for the shoulder *F* (solid with spindle *C*), and the divisions are arranged to read zero when the spindle is at its highest possible position and the stop is bearing against the shoulder. The outer sleeve *D* fits in the hole in the arm, in which it can

rotate and to which it is locked by nut *G*. At its upper portion, it carries the female micrometer thread; the male micrometer part is locked fast in the desired position by the lock-nut *H*. At the bottom part of sleeve *D*, a key is provided which fits in a keyway cut in the spindle *C*, so that the spindle can slide up or down but cannot rotate. This ensures the vertical line of the micrometer to be always on the proper position. By turning the sleeve *D* and locking in its new position the sleeve is turned through the same angle and the carrier and dop, attached thereto, are also rotated through that angle. In that way the same facet of the diamond can be subjected from any desired direction to the action of the grinding wheel. Graduations engraved on the flange of sleeve *D* and on the outside of the arm give that direction. To the bottom of spindle *C* is fixed the carrier, consisting of an arc *J* on which a block *K* slides and can be clamped by screw *L* in any desired position, the angle of inclination being read from graduations on the arc. Dop *M*, to which the

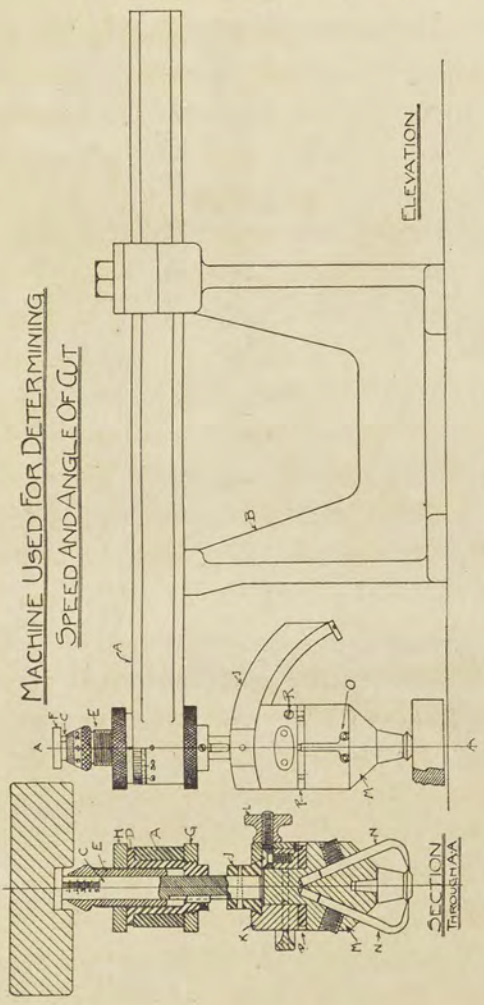

MACHINE USED FOR DETERMINING
SPEED AND ANGLE OF CUT
ELEVATION
SECTION
THROUGH AA

FIGURE 4

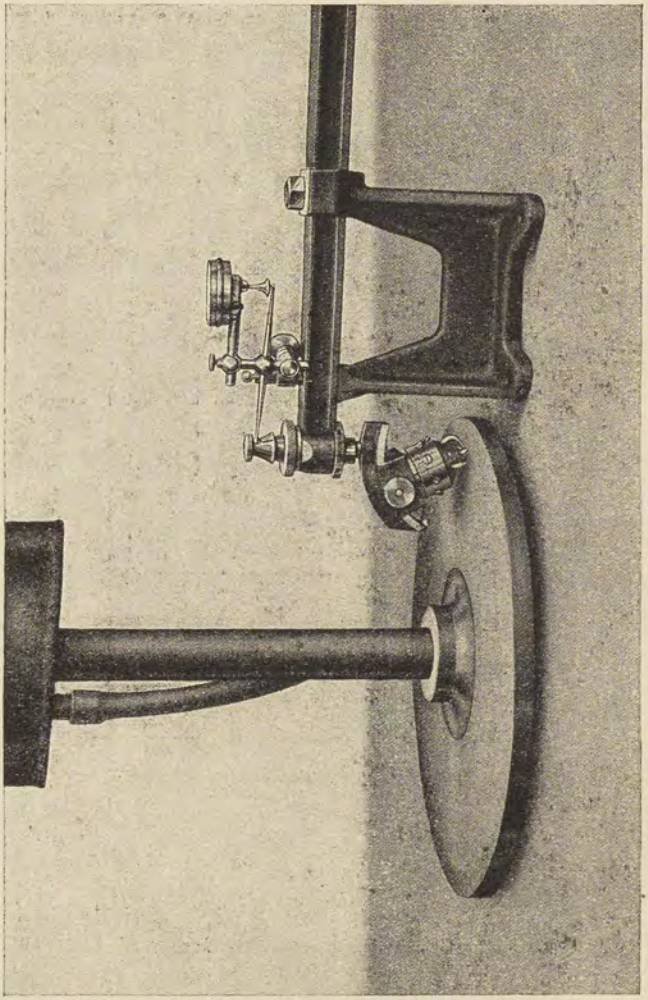


FIGURE 5

stone is held by claws *N*, can rotate freely about its axis in the block *K* and its angular position is determined by the spring stop *O*, fitting in notches in the divided wheel *P*. The wheel *P* itself can be moved about its axis by the screw *R*, this allowing delicate adjustment of the angular position of the dop. The divided wheel was made with eight notches, for the grinding or polishing of brilliants, for which the machine proved very suitable.

The stone being clamped to the dop and placed on the grinding wheel in the desired position (as determined by the divided wheel and ajusting screw, and the divisions on the arc), and being set in the correct direction of grinding by the divisions on the arm and sleeve the micrometer is set at the same distance below the shoulder as it is desired to grind away from the stone, and grinding proceeds until the shoulder meets the stop. [If it is a brilliant that is being polished, the apparatus is then unclamped from the stand, the dop is turned through the desired number of eights of a

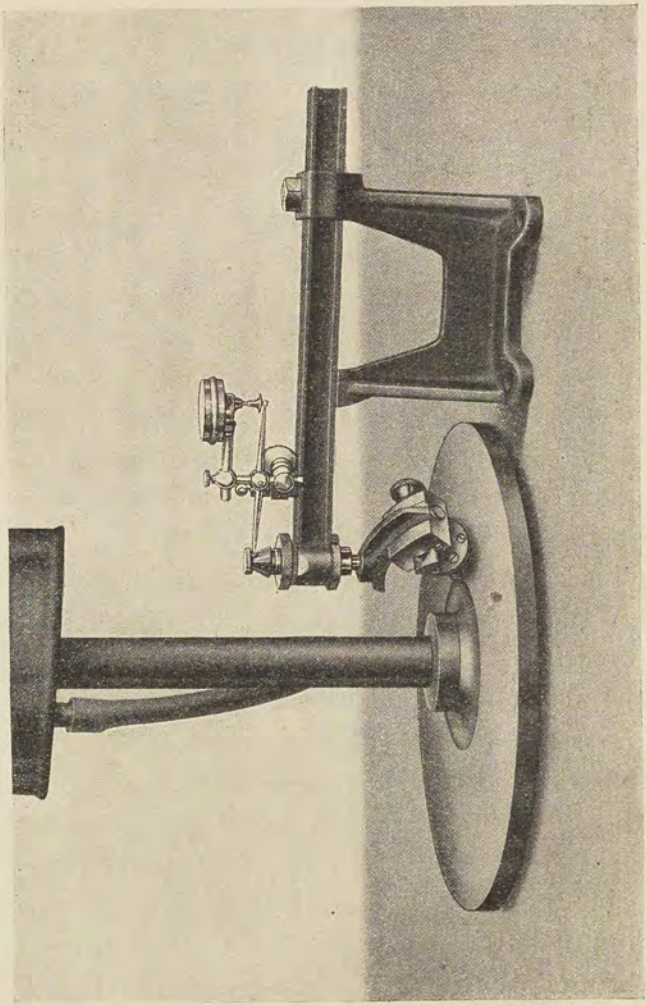


FIGURE 6

circumference, and, if necessary a clamping hook is removed from the corresponding facet after inserting another one on the facet just ground. The former facet is then placed upon the grinding wheel and ground till the stop again meets the shoulder. The same process is repeated for the eight facets, there being provided eight holes in the dop, placed symmetrically round the axis, and eight bolts to clamp the hooks in these holes. (Fuller explanations of the method of grinding brilliants with this machine will be found in the Patent Specifications.)]

To study exactly the behaviour of a stone while being ground, a dial indicator gauge was fitted to the arm (as shown in the photographs), so that the least downward movement of the stone is indicated upon the gauge. It was found easy to read the gauge to the tenthousandth of an inch, the last figure being estimated with a sufficient degree of accuracy.

4. EXPERIMENTS

PART 1.
GRINDING OF ORDINARY STONES

Under his heading cone all experiments made with stones in the course of manufacture into brilliants, i. e. stones being ground into brilliants after sawing, splitting, and cutting (=bruting). These experiments were the first made and they were made at the beginning with the ordinary dops and holder, the amount of material ground off being determined by weighing the diamond before and after grinding: at the time of these trials, neither the special dop and holder nor the bearings described in the preceding pages were ready (as owing to war conditions their delivery was very protracted). These trials could therefore not be made at speeds greater

than 3800 R. P. M. approximately, and were meant to be preliminary tests which might probably fore-shadow what was to be expected from further experiments and, at any rate, indicate in what manner and direction these experiments should usefully be conducted.

Those preliminary tests were made in the following manner:

Stones as similar as possible in shape were selected out of the same parcel of rough diamonds and ground under various conditions of speed, radius, load, these conditions being noted and the amount of material ground off being determined by weighings before and after grinding, and the amount of time taken to grind similar facets being compared.

For comparison stones of widely different sizes were experimented upon.

As in modern practice diamonds are, whenever possible, ground as four-points, i. e. with the girdle of the cut stone co-planar with the square base common to the two pyramids of the rough stone, all the stones

selected were also four-points. The experiments were confined to facets where the loss of weight is large, i. e. to the coins or corner facets of the bottom part of the stone.

The results obtained are as follows, the weight given as lost by grinding being that of the total amount of material removed by the grinding of the four bottom corner-facets. It was found that the weight of each coin separately was too small to give trustworthy results.

A. EXPERIMENTS AT THE NORMAL SPEED, i. e. 2100 R.P.M.

TABLE 1.

No.	Weight of stone before grinding	Weight of stone after grinding	Loss of weight (carats)	Time for grinding minutes	Weight ground per minute (carats)	Diameter of track (inches)	Load on facet (lbs)
1	0.78	0,71	0.07	$49^{1}/_{2}$	0.0014	5	2.4
2	0.80	0.71	0.09	$67^{3}/_{4}$	0.0013	5	2.4
3	0.80	0.69	0.11	$80^{1}/_{2}$	0.0013	5	2.4
4	0.81	0.73	0.08	57	0.0014	5	2.4
5	1.83	1.67	0.16	97	0.0016	$5^{1}/_{4}$	2.4
6	1.85	1.68	0.17	$126^{1}/_{2}$	0.0013	$5^{1}/_{4}$	2.4
7	1.86	1.67	0.19	$150^{3}/_{4}$	0.0012	$5^{1}/_{4}$	2.4
8	1.87	1.67	0.20	$140^{1}/_{4}$	0.0014	$5^{1}/_{4}$	2.4
9	2.94	2.69	0.25	198	0.0012	$5^{1}/_{4}$	2.4
10	2.96	2.68	0.28	199	0.0014	$5^{1}/_{4}$	2.4
11	3.00	2.67	0.33	$220^{1}/_{2}$	0.0014	$5^{1}/_{4}$	2.4
12	3.01	2.72	0.29	$220^{3}/_{4}$	0.0014	$5^{1}/_{4}$	2.4
13	4.06	3.66	0.40	$265^{1}/_{2}$	0.0015	$5^{1}/_{2}$	2.4
14	4.07	3.69	0.38	291	0.0013	$5^{1}/_{2}$	2.4
15	4.10	3.71	0.39	356	0.0011	$5^{1}/_{2}$	2.4
16	4.12	3.68	0.44	$305^{1}/_{2}$	0.0014	$5^{1}/_{2}$	2.4
17	0.81	0.70	0.11	$52^{1}/_{2}$	0.0021	7	2.4
18	0.83	0.74	0.09	$50^{3}/_{4}$	0.0018	7	2.4
19	0.83	0.71	0.12	63	0.0019	7	2.4
20	0.83	0.75	0.08	$44^{1}/_{4}$	0.0018	7	2.4
21	1.88	1.67	0.21	122	0.0017	7	2.4
22	1.89	1.69	0.20	$91^{3}/_{4}$	0.0022	7	2.4
23	1.86	1.68	0.18	$90^{1}/_{2}$	0.0019	7	2.4
24	1.89	1.72	0.17	92	0.0018	7	2.4
25	2.83	2.57	0.26	$147^{3}/_{4}$	0.0017	$7^{1}/_{4}$	2.4
26	2.85	2.58	0.27	142	0.0019	$7^{1}/_{4}$	2.4
27	2.88	2.55	0.33	$163^{1}/_{2}$	0.0020	$7^{1}/_{4}$	2.4

No.	Weight of stone before grinding	Weight of stone after grinding	Loss of weight (carats)	Time for grinding minutes	Weight ground per minute (carats)	Diameter of track (inches)	Load on facet (lbs)
28	2.90	2.59	0.31	161	0.0019	$7\frac{1}{4}$	2.4
29	4.01	3.57	0.44	286	0.0015	$7\frac{1}{2}$	2.4
30	4.03	3.66	0.37	$205\frac{1}{2}$	0.0018	$7\frac{1}{2}$	2.4
31	4.04	3.62	0.42	$197\frac{3}{4}$	0.0021	$7\frac{1}{2}$	2.4
32	4.06	3.73	0.33	173	0.0019	$7\frac{1}{2}$	2.4
33	0.85	0.78	0.07	$27\frac{1}{4}$	0.0026	9	2.4
34	0.85	0.77	0.08	$30\frac{1}{2}$	0.0026	9	2.4
35	0.86	0.78	0.08	35	0.0023	9	2.4
36	0.87	0.76	0.11	$45\frac{1}{4}$	0.0024	9	2.4
37	1.92	1.74	0.18	$70\frac{3}{4}$	0.0025	9	2.4
38	1.93	1.72	0.21	110	0.0019	9	2.4
39	1.95	1.76	0.19	$72\frac{3}{4}$	0.0026	9	2.4
40	1.98	1.75	0.23	92	0.0025	9	2.4
41	3.03	2.78	0.25	$101\frac{1}{2}$	0.0025	$9\frac{1}{4}$	2.4
42	3.05	2.72	0.33	$207\frac{3}{4}$	0.0016	$9\frac{1}{4}$	2.4
43	3.07	2.75	0.32	$135\frac{1}{2}$	0.0024	$9\frac{1}{4}$	2.4
44	3.10	2.82	0.28	108	0.0026	$9\frac{1}{4}$	2.4
45	4.10	3.76	0.34	$141\frac{1}{4}$	0.0024	$9\frac{1}{4}$	2.4
46	4.15	3.73	0.42	170	0.0025	$9\frac{1}{4}$	2.4
47	4.17	3.76	0.41	158	0.0026	$9\frac{1}{4}$	2.4
48	4.18	3.70	0.48	$190\frac{3}{4}$	0.0025	$9\frac{1}{4}$	2.4
49	0.91	0.83	0.08	$44\frac{1}{2}$	0.0018	$5\frac{1}{2}$	3.5
50	0.93	0.82	0.11	$52\frac{1}{2}$	0.0021	$5\frac{1}{2}$	3.5
51	0.95	0.83	0.12	51	0.0023	$5\frac{1}{2}$	3.5
52	0.95	0.85	0.10	$45\frac{1}{4}$	0.0022	$5\frac{1}{2}$	3.5
53	2.01	1.81	0.20	91	0.0022	$5\frac{1}{2}$	3.5
54	2.01	1.77	0.24	$128\frac{3}{4}$	0.0019	$5\frac{1}{2}$	3.5
55	2.02	1.84	0.18	$144\frac{1}{2}$	0.0012	$5\frac{1}{2}$	3.5
56	2.03	1.82	0.21	95	0.0022	$5\frac{1}{2}$	3.5
57	2.89	2.60	0.29	144	0.0020	$5\frac{3}{4}$	3.5
58	2.90	2.59	0.31	$148\frac{1}{4}$	0.0021	$5\frac{3}{4}$	3.5
59	3.06	2.62	0.34	$152\frac{1}{2}$	0.0022	$5\frac{3}{4}$	3.5
60	3.11	2.66	0.35	$169\frac{3}{4}$	0.0020	$5\frac{3}{4}$	3.5
61	3.89	3.50	0.39	207	0.0019	$5\frac{3}{4}$	3.5
62	3.91	3.49	0.42	$200\frac{1}{2}$	0.0021	$5\frac{3}{4}$	3.5
63	3.94	3.57	0.37	$184\frac{1}{4}$	0.0020	$5\frac{3}{4}$	3.5
64	3.95	3.50	0.45	208	0.0022	$5\frac{3}{4}$	3.5
65	0.97	0.90	0.07	$27\frac{1}{2}$	0.0025	$7\frac{1}{2}$	3.5
66	0.99	0.89	0.10	$33\frac{1}{2}$	0.0030	$7\frac{1}{2}$	3.5

No.	Weight of stone before grinding	Weight of stone after grinding	Loss of weight (carats)	Time for grinding minutes	Weight ground per minute (carats)	Diameter of track (inches)	Load on facet (lbs)
67	0.99	0.90	0.09	33	0.0027	$7\frac{1}{2}$	3.5
68	1.01	0.90	0.11	37	0.0029	$7\frac{1}{2}$	3.5
69	2.05	1.80	0.25	$80\frac{1}{4}$	0.0031	$7\frac{3}{4}$	3.5
70	2.07	1.86	0.21	75	0.0028	$7\frac{3}{4}$	3.5
71	2.08	1.90	0.18	$59\frac{1}{2}$	0.0030	$7\frac{3}{4}$	3.5
72	2.11	1.89	0.22	$73\frac{1}{4}$	0.0030	$7\frac{3}{4}$	3.5
73	2.97	2.71	0.26	109	0.0024	$7\frac{3}{4}$	3.5
74	3.07	2.73	0.34	$111\frac{3}{4}$	0.0031	$7\frac{3}{4}$	3.5
75	3.13	2.82	0.31	108	0.0029	$7\frac{3}{4}$	3.5
76	3.14	2.85	0.29	100	0.0029	$7\frac{3}{4}$	3.5
77	4.04	3.68	0.36	$128\frac{1}{2}$	0.0028	8	3.5
78	4.18	3.81	0.37	$120\frac{3}{4}$	0.0031	8	3.5
79	4.20	3.74	0.46	$150\frac{3}{4}$	0.0030	8	3.5
80	4.23	3.80	0.43	149	0.0029	8	3.5
81	2.23	2.01	0.22	57	0.0039	$9\frac{1}{2}$	3.5
82	2.28	2.05	0.23	60	0.0038	$9\frac{1}{2}$	3.5
83	2.31	2.11	0.20	$50\frac{1}{2}$	0.0040	$9\frac{1}{2}$	3.5
84	2.39	2.14	0.25	73	0.0034	$9\frac{1}{2}$	3.5
85	4.30	3.87	0.43	$100\frac{3}{4}$	0.0039	$9\frac{1}{2}$	3.5
86	4.34	3.89	0.45	123	0.0036	$9\frac{1}{2}$	3.5
87	4.41	3.93	0.48	140	0.0037	$9\frac{1}{2}$	3.5
88	4.42	4.03	0.39	$97\frac{1}{2}$	0.0040	$9\frac{1}{2}$	3.5
89	5.57	4.98	0.59	$163\frac{1}{4}$	0.0036	$9\frac{3}{4}$	3.5
90	5.70	5.17	0.53	136	0.0039	$9\frac{3}{4}$	3.5
91	5.95	5.34	0.61	$168\frac{1}{2}$	0.0036	$9\frac{3}{4}$	3.5
92	6.08	5.43	0.65	177	0.0037	$9\frac{3}{4}$	3.5
93	7.89	7.15	0.74	$198\frac{3}{4}$	0.0037	10	3.5
94	7.96	7.14	0.82	$339\frac{1}{2}$	0.0024	10	3.5
95	8.03	7.20	0.83	235	0.0035	10	3.5
96	8.23	7.46	0.77	194	0.0040	10	3.5
97	10.56	9.49	1.07	$272\frac{3}{4}$	0.0039	10	3.5
98	11.71	10.50	1.21	$335\frac{1}{2}$	0.0036	10	3.5
99	12.08	10.69	1.39	346	0.0040	10	3.5
100	12.76	11.35	1.41	$381\frac{1}{4}$	0.0037	10	3.5
101	3.85	3.50	0.35	$93\frac{3}{4}$	0.0037	6	5.2
102	3.87	3.47	0.40	$111\frac{1}{2}$	0.0036	6	5.2
103	3.93	3.51	0.42	120	0.0035	6	5.2
104	3.96	3.58	0.38	$121\frac{3}{4}$	0.0032	6	5.2
105	5.89	5.30	0.59	$193\frac{1}{2}$	0.0030	$6\frac{1}{4}$	5.2

No.	Weight of stone before grinding	Weight of stone after grinding	Loss of weight (carats)	Time for grinding minutes	Weight ground per minute (carats)	Diameter of track (inches)	Load on facet (lbs)
106	5.97	5.36	0.61	166	0.0037	$6\frac{1}{4}$	5.2
107	6.12	5.48	0.64	174	0.0037	$6\frac{1}{4}$	5.2
108	6.22	5.61	0.61	174	0.0035	$6\frac{1}{4}$	5.2
109	7.78	6.99	0.79	$221\frac{1}{4}$	0.0036	$6\frac{1}{2}$	5.2
110	9.64	8.58	1.06	$303\frac{1}{2}$	0.0035	$6\frac{1}{2}$	5.2
111	11.73	10.54	1.19	347	0.0034	$6\frac{1}{2}$	5.2
112	13.32	11.93	1.39	$381\frac{1}{4}$	0.0036	$6\frac{1}{2}$	5.2
113	4.19	3.81	0.38	$79\frac{1}{2}$	0.0048	8	5.2
114	4.27	3.83	0.44	$86\frac{1}{4}$	0.0051	8	5.2
115	4.43	4.07	0.36	71	0.0051	8	5.2
116	4.59	4.12	0.47	$97\frac{1}{2}$	0.0048	8	5.2
117	6.28	5.62	0.64	256	0.0025	8	5.2
118	6.28	5.71	0.57	115	0.0050	8	5.2
119	6.31	5.66	0.65	$126\frac{1}{4}$	0.0051	8	5.2
120	6.34	5.73	0.61	124	0.0049	8	5.2
121	8.08	7.22	0.86	168	0.0051	$8\frac{1}{4}$	5.2
122	9.75	8.73	1.02	$196\frac{1}{2}$	0.0052	$8\frac{1}{4}$	5.2
123	12.00	10.69	1.31	$277\frac{1}{4}$	0.0047	$8\frac{1}{4}$	5.2
124	14.03	12.56	1.47	379	0.0039	$8\frac{1}{4}$	5.2
125	4.72	4.31	0.41	65	0.0063	$10\frac{1}{4}$	5.2
126	4.80	4.30	0.50	$77\frac{3}{4}$	0.0064	$10\frac{1}{4}$	5.2
127	4.84	4.32	0.52	$85\frac{1}{2}$	0.0061	$10\frac{1}{4}$	5.2
128	4.91	4.43	0.48	$79\frac{1}{2}$	0.0060	$10\frac{1}{4}$	5.2
129	6.40	5.72	0.68	106	0.0064	$10\frac{1}{4}$	5.2
130	6.70	6.05	0.65	$98\frac{3}{4}$	0.0066	$10\frac{1}{4}$	5.2
131	6.77	6.07	0.70	$110\frac{1}{2}$	0.0063	$10\frac{1}{4}$	5.2
132	6.82	6.16	0.66	146	0.0045	$10\frac{1}{4}$	5.2
133	7.95	7.10	0.85	$143\frac{3}{4}$	0.0059	$10\frac{1}{2}$	5.2
134	10.03	9.08	0.95	154	0.0062	$10\frac{1}{2}$	5.2
135	11.66	10.49	1.17	180	0.0065	$10\frac{1}{2}$	5.2
136	12.48	11.16	1.32	$290\frac{1}{2}$	0.0063	$10\frac{1}{2}$	5.2

B. EXPERIMENTS AT THE HIGH SPEED, I. E. 3700 R. P. M.

In this group of experiments, only an single track was tried, i. e., one with a diameter of about $8^1/_2$ inches: It was considered best to do all experiments on a single grinding wheel, so as to eliminate any possible variation due to an eventual defect in the casting; and the diameter of $8^1/_2$ was the only one still usable after the great number of previous experiments, although these had been performed with the utmost care so as to spoil as little of the lap as possible.

TABLE 2.

No.	Weight before grinding	Weight after grinding	Loss of weight (carats)	Time for grinding (minutes)	Weight ground per minute	Diameter of track (inches)	Load on facet (lbs)
1	1.25	1.10	0.15	$35^1/_4$	0.0042	$8^1/_4$	2.4
2	1.29	1.18	0.11	29	0.0038	$8^1/_4$	2.4
3	1.32	1.19	0.14	$32^1/_2$	0.0043	$8^1/_4$	2.4
4	1.36	1.21	0.15	34	0.0044	$8^1/_4$	2.4
5	3.09	2.76	0.33	75	0.0044	$8^1/_4$	2.4
6	3.17	2.81	0.36	$79^1/_2$	0.0045	$8^1/_4$	2.4

No.	Weight before grinding	Weight after grinding	Loss of weight (carats)	Time grinding (minutes)	Weight ground per minute	Diameter of track (inches)	Load on facet (lbs)
7	3.20	2.89	0.31	82 3/4	0.0038	8 1/4	2.4
8	3.25	2.96	0.29	78	0.0037	8 1/4	2.4
9	4.56	4.11	0.45	110	0.0041	8 1/4	2.4
10	4.97	4.49	0.58	138 1/4	0.0042	8 1/4	2.4
11	4.86	4.38	0.48	126	0.0038	8 1/4	2.4
12	4.98	4.52	0.46	118 1/2	0.0039	8 1/4	2.4
13	1.30	1.18	0.12	21 3/4	0.0056	8 1/4	3.5
14	1.37	1.24	0.13	49 1/2	0.0026	8 1/4	3.5
15	1.39	1.24	0.15	29 3/4	0.0051	8 1/4	3.5
16	1.43	1.31	0.12	22	0.0054	8 1/4	3.5
17	3.28	3.00	0.28	58 1/4	0.0048	8 1/2	3.5
18	3.30	2.97	0.33	66	0.0050	8 1/2	3.5
19	3.36	2.99	0.37	67	0.0054	8 1/2	3.5
20	3.39	3.08	0.31	56 1/4	0.0055	8 1/2	3.5
21	4.98	4.47	0.51	102	0.0050	8 1/2	3.5
22	5.01	4.49	0.52	96 1/2	0.0053	8 1/2	3.5
23	5.03	4.43	0.58	108	0.0054	8 1/2	3.5
24	5.06	4.54	0.52	176 3/4	0.0030	8 1/2	3.5
25	3.59	3.19	0.30	35 1/2	0.0085	8 1/2	5.2
26	3.67	3.33	0.34	37 1/2	0.0091	8 1/2	5.2
27	3.83	3.43	0.40	45 1/4	0.0088	8 1/2	5.2
28	3.90	3.51	0.39	96 1/2	0.0041	8 1/2	5.2
29	6.71	6.07	0.64	77 1/4	0.0083	8 3/4	5.2
30	6.73	6.06	0.67	73 1/2	0.0091	8 3/4	5.2
31	6.89	6.15	0.74	82	0.0090	8 3/4	5.2
32	6.93	6.27	0.66	110 3/4	0.0059	8 3/4	5.2
33	8.08	7.24	0.84	91	0.0093	8 3/4	5.2
34	8.93	8.02	0.91	147 1/2	0.0062	8 3/4	5.2
35	10.56	9.46	1.10	118	0.0093	8 3/4	5.2
36	12.20	11.03	1.17	140	0.0084	8 3/4	5.2

In all these experiments, the time taken for grinding is the time the facet is actually in contact with the grinding wheel and loaded with the loads as indicated. The time during which the load was

removed and the facet examined is thus deducted.

As is seen above, a great number of stones were experimented with: this was necessary owing to the great variability of the results, arising from one more of the following reasons:

(1) There is some impurity in the facet ground which interfered with the grinding process.

(2) The stone is not placed absolutely correctly in the direction of least hardness.

(3) The facet ground is not in exactly the same direction with regard to the axes of installisation in every instance.

(4) The condition of the track may not be the same.

During the experiments, all possible precautions were taken to avoid, as far as possible, the irregularities in the results due to one of the above causes:

The whole of the stones ground came from the same parcel of regularly crystallised pure, (closed) goods, every stone was examined with a high-power lens, and only

stones where no defect of any kind could be detected were used in the experiments. The greatest care was taken when placing the stones on the grinding wheel that they should be all in the direction of least hardness, i. e. of greatest ease of cut. One grinding wheel was used throughout, and the stones were placed on the wheel with the utmost care, so as to injure the cast iron as little as possible and avoid any scratches which might be caused by a too sudden contact (chiefly at the beginning of the facet): in this manner 172 stones could be experimented upon. Also, the diamonds were ground in groups of four and were left in the same track until for some cause or other the track was injured; then they were shifted by a small amount and a (partly) new track formed at a slightly greater diameter, the track being kept in the same condition throughout the experiments.

Let us now examine the results of the trials on the 172 diamonds as given in the preceding pages. It will be noted that there is a very well defined tendency for

the weight of diamond ground per minute to be constant at identical conditions of speed of rotation, diameter of track, and load, independently of the size of the stone ground. The variation (in *absolutely sound stones*) amounts to about 10 to 15 per cent on either side of the average. It is to be pointed out here that this amount of variation must be regarded as very small, and that if the experiments had been performed with less care, the variation might easily have been two or threefold. It is to be borne in mind in his respect what will be proved by later trials, i. e. that the direction of least hardness is very definite and that the ease with which the diamond is ground decreases rapidly for small angular changes in this direction.

A few stone hovewer do not come within the limits specified above theo proved ty be harder to grind than to remainder. They are numbers 38, 42, 55, 94, 117, 124 and 132 at 2100 revolutions per minute, and numbers 14, 24, 28, 32 and 34 at 3760 revolutions per minute.

The weight ground per minute for all the above stones is very markedly below that for the others ground under the same conditions. In the case of many of them, the cause of this difference could be traced to the presence of impurities, chiefly glesses, which had eluded previous observation, but which became apparent upon grinding; another cause was the presence of small naats, that is, small portions of diamond confined by two cleavage planes, and in which the direction of crystallisation is symmetrically reversed. Frequently these naats go right through the stone, and in that case they are generally easily seen. But sometimes they are confined to one particular part and are very small. Then they may avoid detection, but they will render the grinding process more difficult, and sometimes the intersection between the cleavage planes where the crystallisation changes and the plane of the facet will be marked be faint lines on the ground surface, which cannot be removed by polishing. This was seen to be the case in No. 23 (3760 R. P.M.) and may

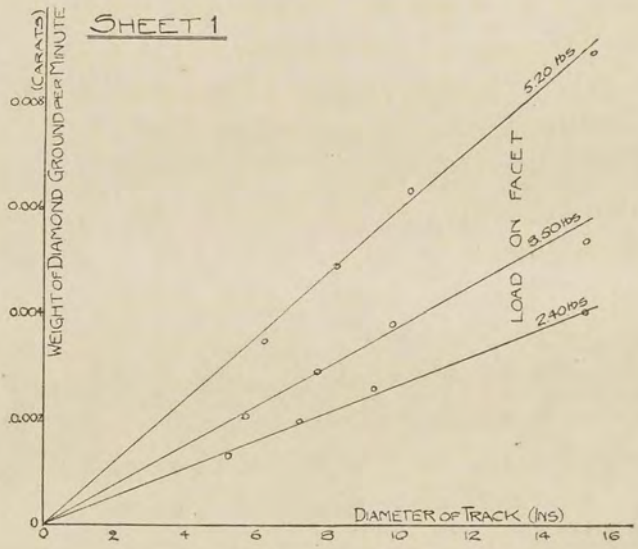
have been the cause of the difficulty with which the diamond was ground in the stones where the reason for the slowness of the grinding process was not apparent.

If these obviously abnormal results are neglected, and the means of the remaining values for the weight ground per minute taken, we obtain values for that variable as tabulated below:

TABLE 3.

Speed of grinding wheel (R.P.M.)	Diameter of grinding track (inches)	Load on diamond (lbs.)	Weight ground per minute (carats)
2100	5 to $5\frac{1}{2}$	2.4	0.00135
2100	7 ,, $7\frac{1}{4}$	2.4	0.00188
2100	9 ,, $9\frac{1}{4}$	2.4	0.00250
2100	$5\frac{1}{2}$,, $5\frac{3}{4}$	3.5	0.00208
2100	$7\frac{1}{2}$,, $7\frac{3}{4}$	3.5	0.00287
2100	$9\frac{1}{2}$,, 10	3.5	0.00376
2100	6 ,, $6\frac{1}{2}$	5.2	0.00350
2100	8 ,, $8\frac{1}{4}$	5.2	0.00498
2100	$10\frac{1}{4}$,, $10\frac{1}{2}$	5.2	0.00627
3760	$8\frac{1}{4}$	2.4	0.00408
3760	$8\frac{1}{4}$,, $8\frac{1}{2}$	3.5	0.00525
3760	$8\frac{1}{2}$,, $8\frac{3}{4}$	5.2	0.00888

If the above values of weight of diamond ground per minute are plotted on a base of grinding track diameter (sheet 1), it will be seen that these variables follow a straight line law within limits of error which, as shown above, are unavoidable and must


SHEET 1
WEIGHT OF DIAMOND GROUND PER MINUTE (CARATS)
0.008
0.006
0.004
0.002
0
DIAMETER OF TRACK (INS)
0
2
4
6
8
10
12
14
16
LOAD ON FACET
5.20 lbs
3.50 lbs
2.40 lbs

be considered as very narrow, if we take into consideration the results which would — and were — obtained if very special care is taken in the selection or grinding of the stones or if only a small number of rough diamonds is experimented upon.

At constant speed of the grinding wheel, the rate of grinding is thus proportional to the diameter of the grinding track.

Let us now assume that this means that the rate of grinding is proportional to the linear speed of the track, and let us convert the diameter of the track used at 3760 revolutions per minute into a diameter which would give the same linear speed to the track at 2100 revolutions per minute; or, to put it another way, let us consider the scale of diameter of track to be a scale of linear velocity of track; then the virtual diameter at 2100 R.P.M. corresponding to the diameter of $8\frac{1}{2}''$ at 3760 R.P.M. is

$$8\frac{1}{2} \times \frac{3760}{2100} = 15\frac{1}{2}''$$

Let us plot the value of the weight ground per minute at 3760 R.P.M. at that abscissa. Then the points obtained fall on nor near the straight lines already drawn. This shows that our assumption was correct and that, other things being equal:

(1) The weight of diamond ground per minute is proportional to the linear velocity of the grinding track.

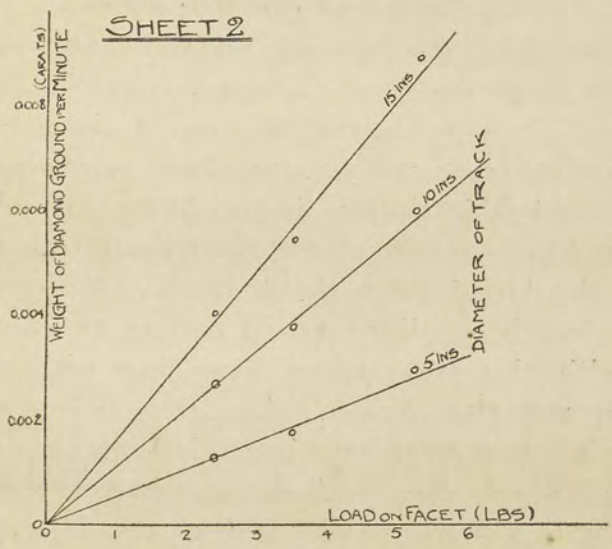
If from the curves of sheet 1 we take values of the weight ground per minute at constant diameters (say 5, 10 and 15 inches) and plot them on a load base (sheet 2) we see that, other things being equal:

(2) The weight of diamond ground per minute is proportional to the load on the facet ground.

From a consideration of table No 3 we know also that, other things being equal:

(3) The weight of diamond ground per minute is independant of the size of the facet ground.

The above conclusions, owing to the unavoidable variability of the results, cannot yet be regarded as final, but only as approxi-


SHEET 2
WEIGHT OF DIAMOND GROUND PER MINUTE (CARATS)
0.003
0.002
0
LOAD ON FACET (LBS)
0
1
2
3
4
5
6
1.5 INS
1.0 INS
0.5 INS
DIAMETER OF TRACK

mate: a nearer approximation can of course be obtained by multiplying the tests still further, but a shorter and more accurate and satisfactory method was devised which will be described in the following pages.

It is of importance to have accurate values for the rate of grinding; for we know that this rate increases approximately as the linear speed of the grinding track. It is quite possible that at a small diameter of that track, the curvature being relatively considerable, the grinding would not proceed at all points of the facet, along the direction of least hardness, so that the results obtained might be smaller than on a track moving with the same linear speed but with a greater diameter; it might thus be more advantageous to have large diameter grinding wheels than small diameter ones revolving at a proportionally higher rate. It was found practically impossible to determine this by the method just used, for the reasons already stated.

PART 2.

GRINDING OF SPECIAL STONES

As has been seen in the preceding part, the grinding of ordinary stones, although very rich in suggestions and in highly important conclusions, is not accurate enough to give full and decisive results:

It was therefore decided to use the special dop, by which not only the total amount of diamond ground could be measured, but also, by the introduction of the dial indicator gauge, the amount ground at any time during the grinding, and this without removing the stone from the dop: the stone could thus be subjected to altered conditions of speed, load or track diameter, without any necessity to remove it for weighing.

Now upon the insertion of an ordinary stone in the dop, it was found, that, other things being equal, the rate of grinding (as measured

in inches of diamond removed per minute) decreased as the area ground increased. As it was found impracticable to measure that area with accuracy at all stages of the grinding, it was decided to make test-pieces of a special shape, such that the area of cross-section should remain constant throughout their length. Two types of test-pieces were made, both prismatic; the first type of a rhomboïdal or parallelogrammatic, and the second of a triangular cross-section.

The first type of prism is bounded by four cleavage planes, and the second, the most frequently used, by two cleavage planes and one sawn surface. The prisms were chosen as large as possible and obtained from large stones.

The stones from which prisms come were carefully watched during all stages of manufacture, and the prisms were only considered suitable if the stones proved to be flawless and of absolutely regular crystallisation throughout. The prism was then set in the special dop with the axis co-incident with the axis of the dop, so

that all inclinations given to the dop and read off the scale would also give the inclination of the prism. Care was taken in setting up the machinery to make both the axis of the spindle of the grinding wheel and that of the spindle of the dop truly vertical, so that these inclinations can be taken as correct.

The experiments made with these shapes of diamond were also divided in two groups, i. e.

(1) Constant inclination trials (inclination = 0)

(2) Variable inclination trials.

GROUP 1.

CONSTANT INCLINATION TRIALS

In the constant inclination trials, the inclination selected was 0, i.e. the axis of the prism was perpendicular to the plane of the grinding wheel. This inclination was selected not only because of the ease with which adjustments could be made and the comparative safety with which the diamond could be subjected to heavy loading (the stress upon the prism being axial). The chief reason was that the plane of grinding corresponds then exactly with the plane of grinding of the table of a 2-point and approximately with the corner facets of a 4-point. Now, in the grinding of brilliants the greatest amount of material is ground away when abrading these last facets; and it is thus most important to examine the behaviour of the diamond when ground in this plane (rather than any other).

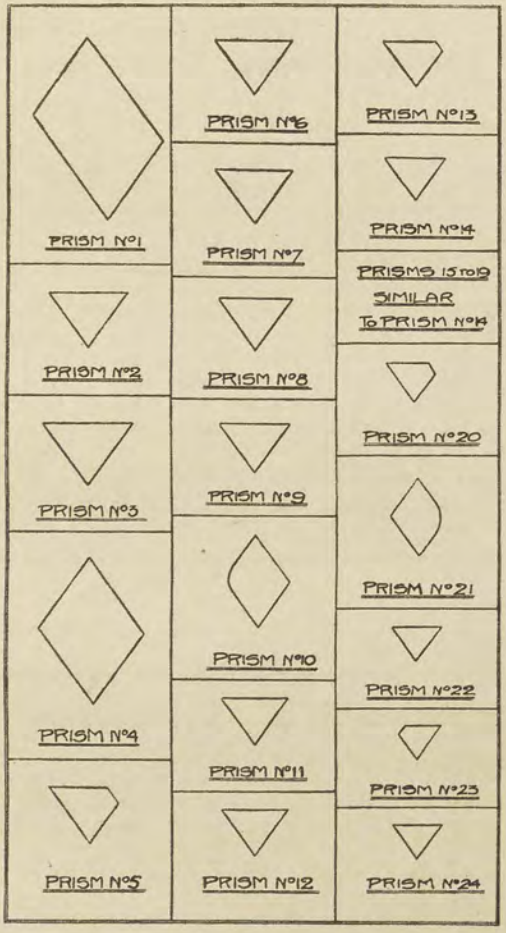
In the experiments made in this group, the direction of greatest ease of grinding of the facet was first determined by trial. This direction was found to be perpendicular to the sawn face of the prism or to the minor diagonal of the rhombus.

The diamonds were held in this position throughout this group of experiments, the prisms being chosen particularly long so that each prism could last throughout this group of experiments from the beginning up to the end. This eliminated any possibility of error which might have otherwise been introducted by difference in area, position, direction of grinding, or, perhaps also, in the hardness of the various prisms ground.

Even a few experiments proved very definite as regards the various relations between all the variables investigated, for the same facet; to obtain however accurate quantitative values, a large number of prisms were ground: in this way the results obtained could be compared with those in Part I (trials on ordinary stones).

It was not considered necessary to give the complete results and the consequent sheets of curves in more than two cases chosen as typical as the values obtained are so very definite and the consequent relations so very well marked. The curves drawn for the trials of all the other stones were in all respects similar, and therefore only the final quantitative coefficients are given.

The area of cross-section of the specimens was calculated from large scale drawings derived from measurements taken on the prisms with a micrometer. The cross-section drawings of the various prisms tested will be found on sheet 3. The results are given on tables 4 to 12. It is to be noted here that, for simplicity, the decimal point was omitted in front of the first zero. The denomination at the top left-hand corner of the tables indicates that the horizontal row next to it is the load and the column under it the time.



CROSS-SECTIONS OF PRISMS TESTED

SHEET 3

Prism 1:

Parallelogrammatic Cross – Section

Area = 0.1738 Sq. inches.

A. Speed 2150 R.P.M.*

(a) diameter of track = 5″ (sheet 4).

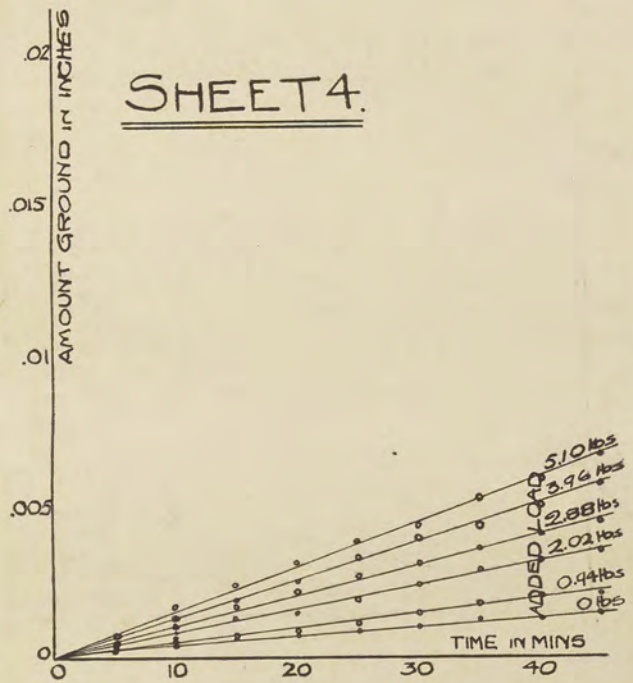
TABLE 4.

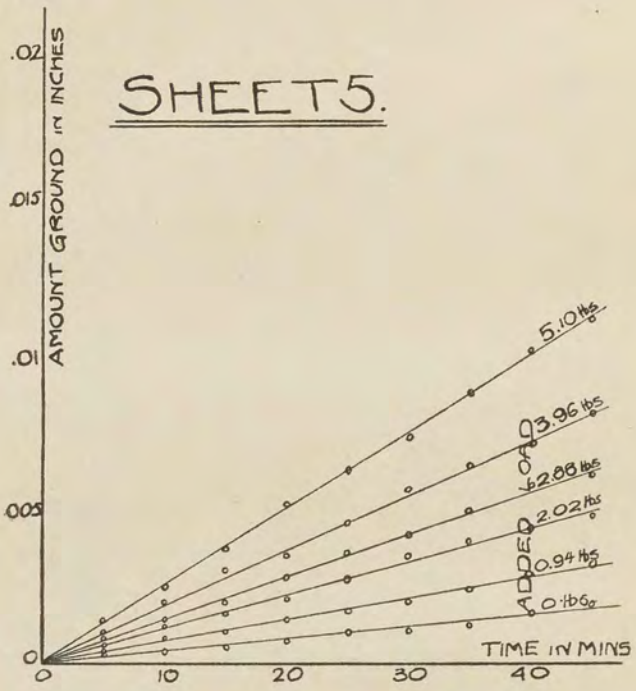
Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
5	0002	0002	0003	0005	0007	0007
10	0004	0005	0006	0010	0013	0016
15	0006	0007	0013	0017	0019	0024
20	0007	0009	0015	0022	0025	0031
25	0008	0011	0019	0027	0033	0038
30	0010	0014	0024	0031	0039	0043
35	0012	0018	0029	0038	0043	0052
40	0012	0020	0032	0040	0050	0058
45	0014	0021	0035	0044	0057	0066
Rate of grinding (inches per minute)	00003	00005	00008	00010	00013	00015

(b) diameter of track = $7\frac{1}{2}$″ (sheet 5).

TABLE 5.

Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
5	0003	0004	0006	0008	0009	0014
10	0004	0008	0012	0014	0020	0025
15	0005	0010	0015	0020	0030	0037
20	0007	0014	0021	0028	0037	0051
25	0010	0017	0027	0035	0045	0062
30	0010	0020	0034	0041	0056	0073
35	0012	0024	0039	0049	0064	0088
40	0016	0029	0043	0057	0071	0101
45	0019	0032	0047	0061	0081	0112
Rate of grinding (inches per minute)	00004	00007	00011	00014	00018	00025


SHEET 4.
AMOUNT GROUND IN INCHES
.02
.015
.01
.005
0
0
10
20
30
40
TIME IN MINS
ADDED LOAD
5.10 lbs
3.96 lbs
2.88 lbs
2.02 lbs
0.94 lbs
0 lbs


SHEET 5.
AMOUNT GROUND IN INCHES
.02
.015
.01
.005
0
0
10
20
30
40
TIME IN MINS
ADDED OF
5.10 lbs
3.96 lbs
2.88 lbs
2.02 lbs
0.94 lbs
0 lbs

A. Speed = 2150 R.P.M. (cont).
(c) diameter of track = 10″ (sheet 6).

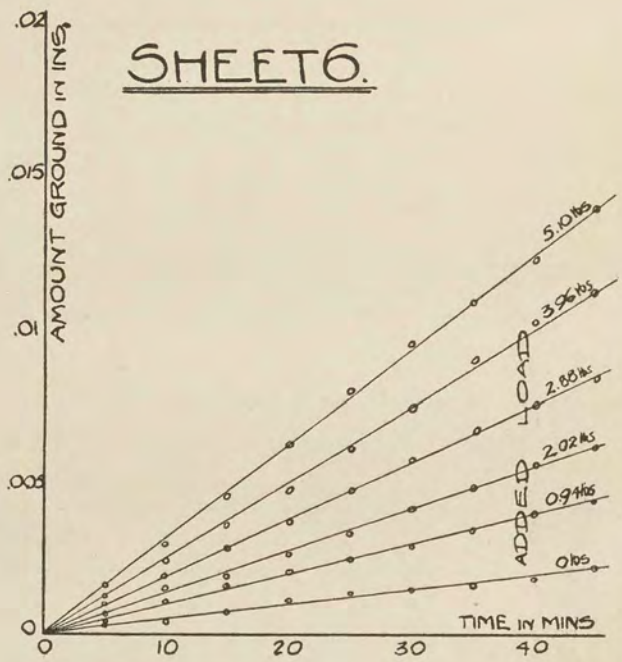
TABLE 6.

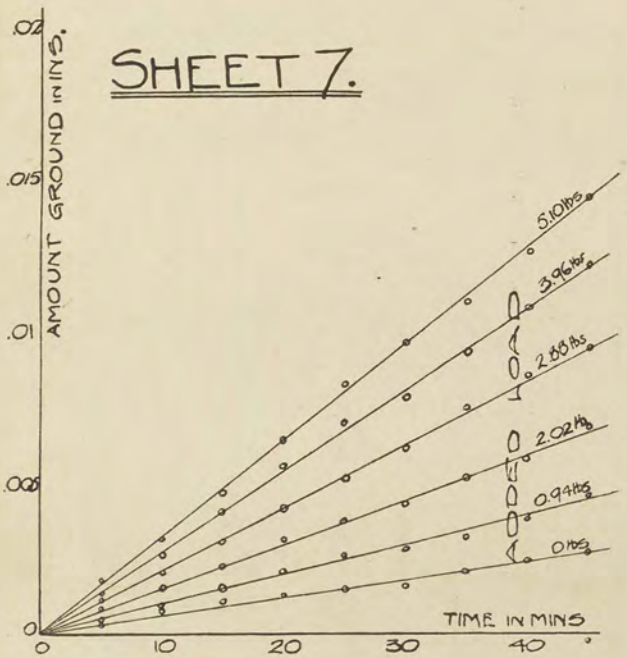
Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
5	0003	0004	0006	0010	0012	0016
10	0004	0010	0015	0019	0024	0029
15	0007	0015	0019	0024	0036	0045
20	0011	0020	0026	0037	0048	0062
25	0013	0024	0033	0047	0061	0080
30	0015	0029	0041	0058	0075	0095
35	0016	0034	0048	0067	0090	0108
40	0018	0040	0056	0075	0102	0122
45	0022	0044	0062	0083	0112	0139
Rate of grinding (inches per minute)	00005	00010	00014	00019	00025	00031

B. Speed = 4500 R.P.M.
(a) diameter of track = 5″ (sheet 7).

TABLE 7.

Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
5	0003	0005	0008	0011	0013	0018
10	0007	0009	0015	0020	0026	0032
15	0010	0015	0022	0030	0040	0047
20	0012	0020	0031	0042	0056	0064
25	0015	0026	0037	0052	0070	0082
30	0016	0028	0043	0061	0078	0096
35	0020	0032	0052	0075	0093	0109
40	0024	0038	0059	0085	0101	0126
45	0027	0046	0068	0094	0111	0143
Rate of grinding (inches per minute)	00006	00010	00015	00021	00027	00032


SHEET 6.
AMOUNT GROUND IN INS.
.02
.015
.01
.005
0
TIME IN MINS
0
10
20
30
40
ADDED LOAD
5.10 lbs
3.96 lbs
2.88 lbs
2.02 lbs
0.94 lbs
0 lbs


SHEET 7.
AMOUNT GROUND IN INS.
.02
.015
.01
.005
0
5.10 lbs
3.96 lbs
2.88 lbs
2.02 lbs
0.94 lbs
0 lbs
TIME IN MINS
0
10
20
30
40

Prism 1:

B. Speed = 4500 R.P.M. (cont).

(b) diameter of track = $7^1/_2$ (sheet 8).

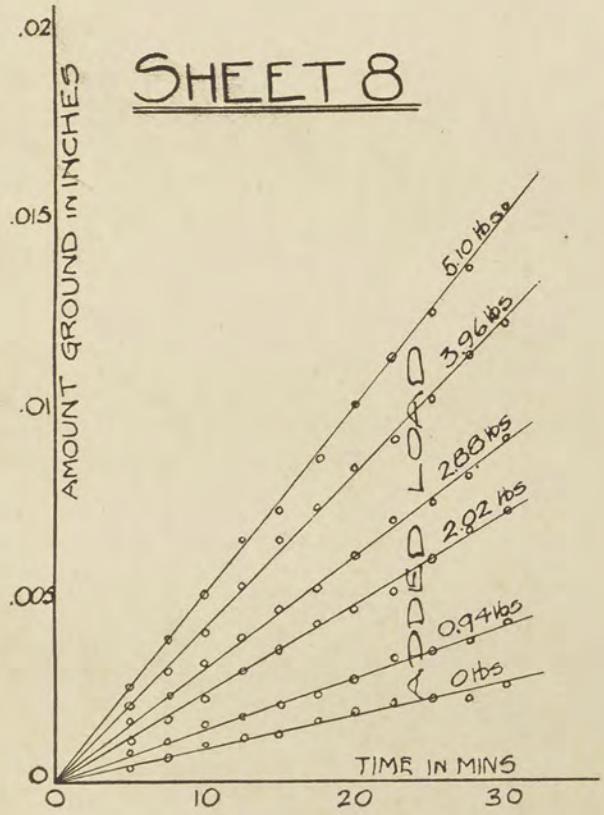
TABLE 8.

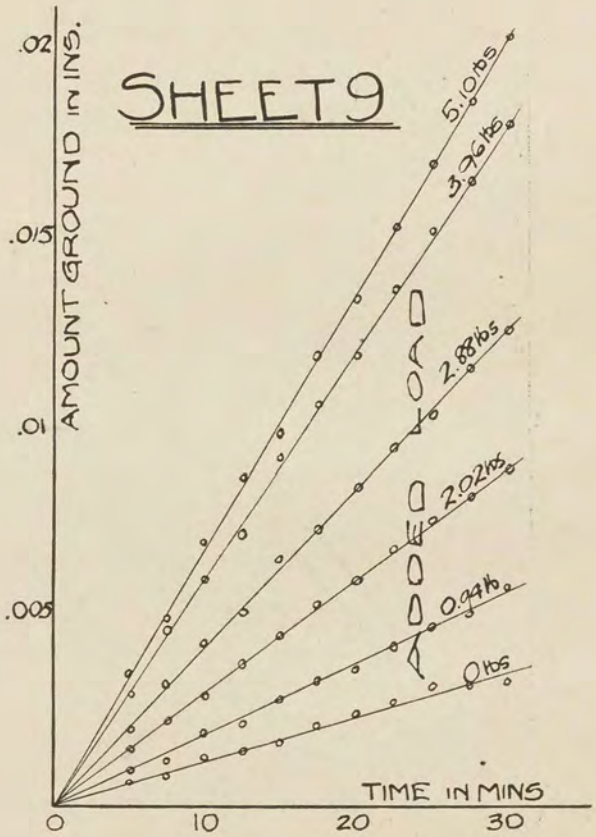
Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
5	0003	0007	0011	0016	0020	0026
$7^1/_2$	0006	0009	0017	0023	0030	0038
10	0011	0015	0022	0032	0040	0050
$12^1/_2$	0013	0017	0030	0039	0052	0064
15	0014	0021	0035	0046	0064	0072
$17^1/_2$	0016	0023	0042	0052	0072	0086
20	0018	0027	0046	0060	0083	0100
$22^1/_2$	0021	0033	0050	0069	0091	0112
25	0022	0035	0060	0074	0101	0122
$27^1/_2$	0022	0037	0067	0081	0113	0136
30	0026	0042	0072	0091	0121	0152
Rate of grinding (inches per minute)	00009	00014	00024	00030	00041	00050

(c) diameter of track = 10″ (sheet 9).

TABLE 9.

Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
5	0006	0010	0016	0021	0030	0035
$7^1/_2$	0008	0013	0023	0033	0046	0050
10	0013	0020	0030	0043	0060	0070
$12^1/_2$	0015	0022	0038	0051	0072	0087
15	0017	0028	0035	0065	0092	0098
$17^1/_2$	0022	0034	0053	0073	0105	0118
20	0025	0037	0060	0085	0118	0133
$22^1/_2$	0027	0042	0068	0094	0135	0152
25	0032	0048	0075	0103	0150	0168
$27^1/_2$	0032	0051	0081	0115	0164	0175
30	0033	0057	0089	0125	0179	0184
Rate of grinding (inches per minute)	00012	00019	00030	00042	00060	00067


SHEET 8
.02
.015
.01
.005
0
AMOUNT GROUND IN INCHES
LOAD
5.10 lbs
3.96 lbs
2.88 lbs
2.02 lbs
0.97 lbs
0 lbs
TIME IN MINS
0
10
20
30


SHEET 9
AMOUNT GROUND IN INS.
.02
.015
.01
.005
LOADED
5.10 lbs
3.76 lbs
2.88 lbs
2.02 lbs
0.94 lb
0 lbs
TIME IN MINS
0
10
20
30

At this point of the experiment the claws which hold the prism to the dop began to touch the grinding wheel.

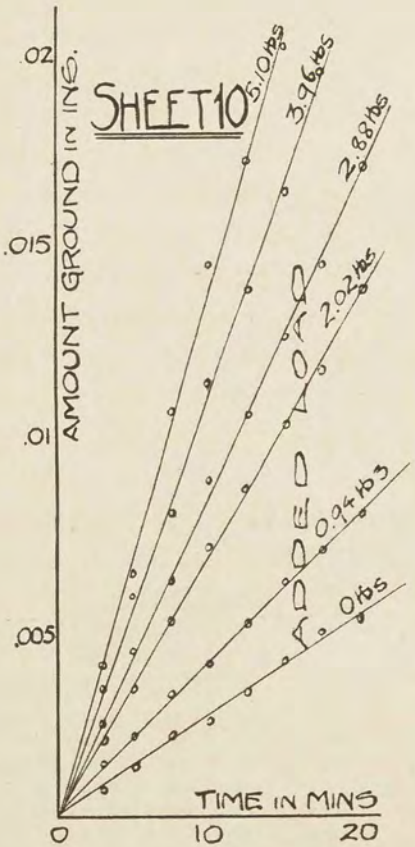
The claws were therefore shifted down into the dop by a slight amount (as much as was possible) good care being taken not to alter in the least the position of the stone; and, so as to have an experiment covering as wide a range as possible, the speed was then altered to the utmost, i.e. 9420 R.P.M., and the stone placed on the 10″ diameter track.

Prism 1

C. Speed = 9420 R.P.M.
diameter of track = 10 inches (sheet 10).

TABLE 10.

Load lbs. / Time mins	0	0.94	2.02	2.88	3.96	5.10
0	0000	0000	0000	0000	0000	0000
$2^1/_2$	0007	0012	0021	0025	0034	0040
5	0013	0022	0034	0044	0058	0064
$7^1/_2$	0022	0033	0051	0062	0080	0108
10	0026	0040	0071	0088	0114	0144
$12^1/_2$	0033	0051	0086	0105	0138	0172
15	0041	0062	0103	0125	0163	0202
$17^1/_2$	0048	0070	0117	0145	—	—
20	0052	0079	0138	0170	—	—
Rate of grinding inches per minute	00027	00040	00069	00085	00112	00138


SHEET 10
.02
.015
.01
.005
AMOUNT GROUND IN INS.
5.10 lbs
3.96 lbs
2.88 lbs
2.02 lbs
0.94 lbs
0 lbs
ADDED LOAD
TIME IN MINS
0
10
20

To obtain more accurate results, the rates of grinding given under each of the tables of results were obtained by plotting curves between the time and the reading on the gauge (sheets 3 to 9). The time was read from a stop watch, and it was thus easy to set the time reading to zero after the conclusion of each vertical column of readings. The gauge could also easily be set to zero in any position by turning the dial round until the zero was co-incident with the pointer. Any slight error in the setting of these zeros could be corrected on the curves.

Let us now tabulate the rate of grinding as obtained from sheets 3 to 9 for the various loads at the different speeds and diameters.

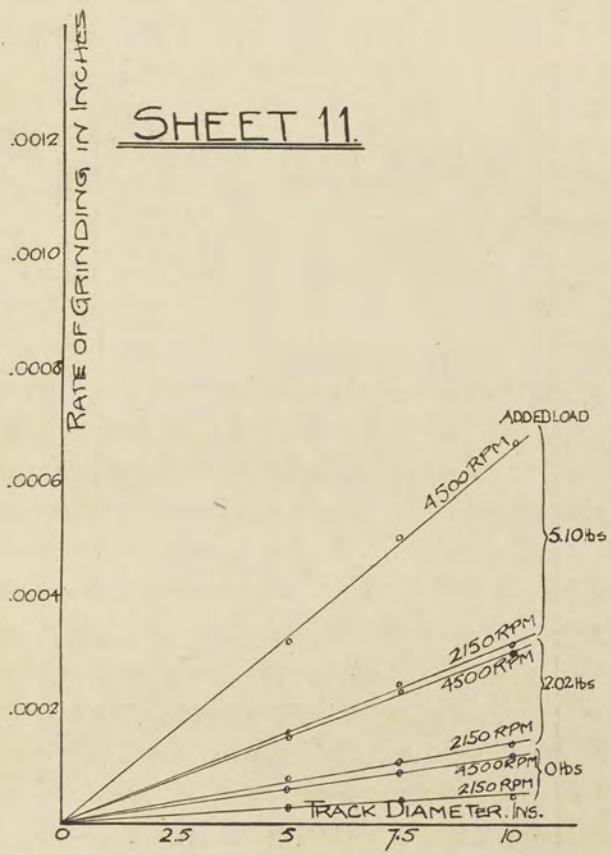
Let us at the same time correct the value of the load by adding the weight of the movable part of the dop itself, as weighed when in position, i. e. 0.88 lbs.

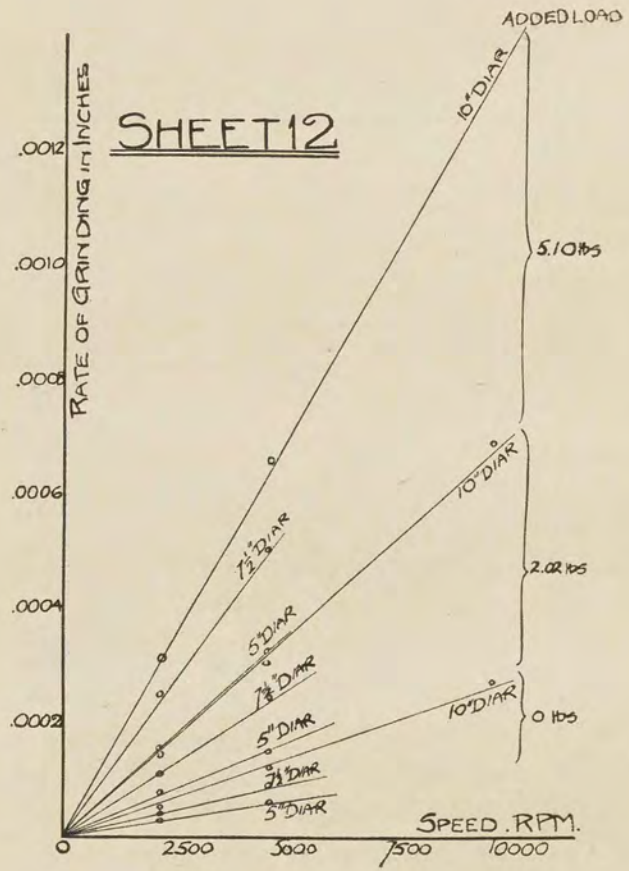
TABLE II.

	Added Load lbs.	0	0.94	2.02	2.88	3.96	5.10	
	Calculated load	0.88	1.82	2.90	3.76	4.84	5.98	Linear velocity of grinding Track (feet per minute)
Speed R.P.M.	True Load lbs. / Track diameter inches	1.15	2.09	3.17	4.03	5.11	6.25	
2150	5	00003	00005	00008	00010	00013	00015	2810
	$7^1/_2$	00004	00007	00011	00014	00018	00025	4220
	10	00005	00010	00014	00019	00025	00031	5680
4500	5	00006	00010	00015	00021	00027	00032	5900
	$7^1/_2$	00009	00014	00024	00030	00041	00050	8830
	10	00012	00019	00030	00042	00060	00067	11800
9420	10	00027	00040	00069	00085	00112	00138	24700

If we plot the rate of grinding against the diameter of the track on the grinding wheel, for constant speeds and loads (sheet 11) we see that *that rate is directly proportional to the diameter of the grinding track:* a deviation from the proportionality due to increased curvature at small diameters is not marked and must be very slight (well within 3%) although it might become appreciable if the diameter be much diminished or the size of the facet ground greatly increased.

If we plot the rate of grinding against the speed, for constant load and diameters, (sheet 12) we see that *that rate is also*


SHEET 11.
RATE OF GRINDING IN INCHES
.0012
.0010
.0008
.0006
.0004
.0002
ADDED LOAD
4500 RPM
5.10 lbs
2150 RPM
4500 RPM
2.02 lbs
2150 RPM
4500 RPM
0 lbs
2150 RPM
TRACK DIAMETER. INS.
0
2.5
5
7.5
10


SHEET 12
RATE OF GRINDING IN INCHES
.0012
.0010
.0008
.0006
.0004
.0002
0
2500
5000
7500
10000
SPEED. RPM.
ADDED LOAD
10" DIAR
5.1 lbs
10" DIAR
2.02 lbs
10" DIAR
0 lbs
1½" DIAR
5" DIAR
1⅛" DIAR
5" DIAR
2¼" DIAR
3" DIAR

directly proportional to the speed of the grinding wheel.

The rate of grinding being proportional both to the diameter of the grinding track and to the number of revolutions per minute of the grinding wheel, it follows that, (as before) *it is proportional* to their product i.e. *to the linear velocity of the grinding track* (sheet 13).

A column is thus added to the above table, in which column the linear speed of the grinding track is given.

It was obtained by the formula

$$V = N \times \frac{\pi d}{12}$$

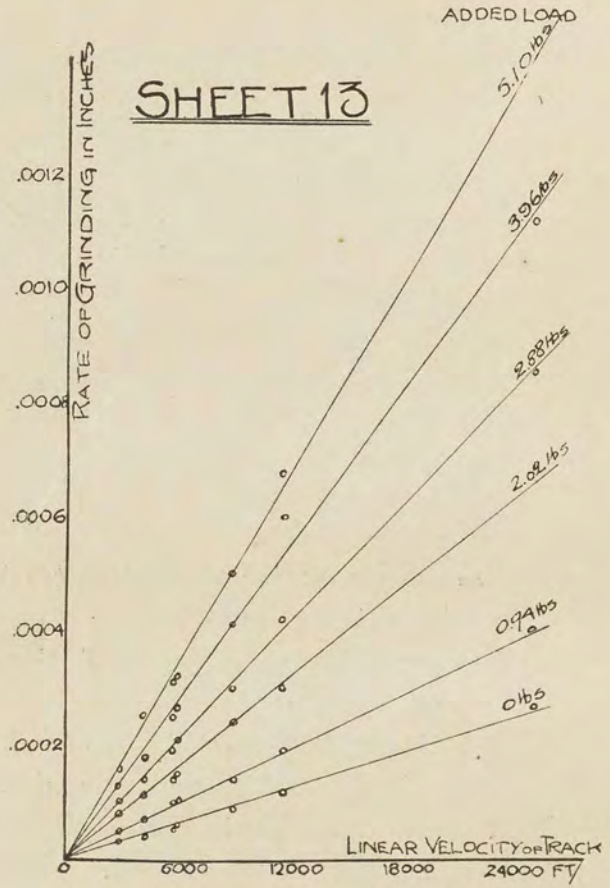
where V = linear velocity of grinding track in feet per minute

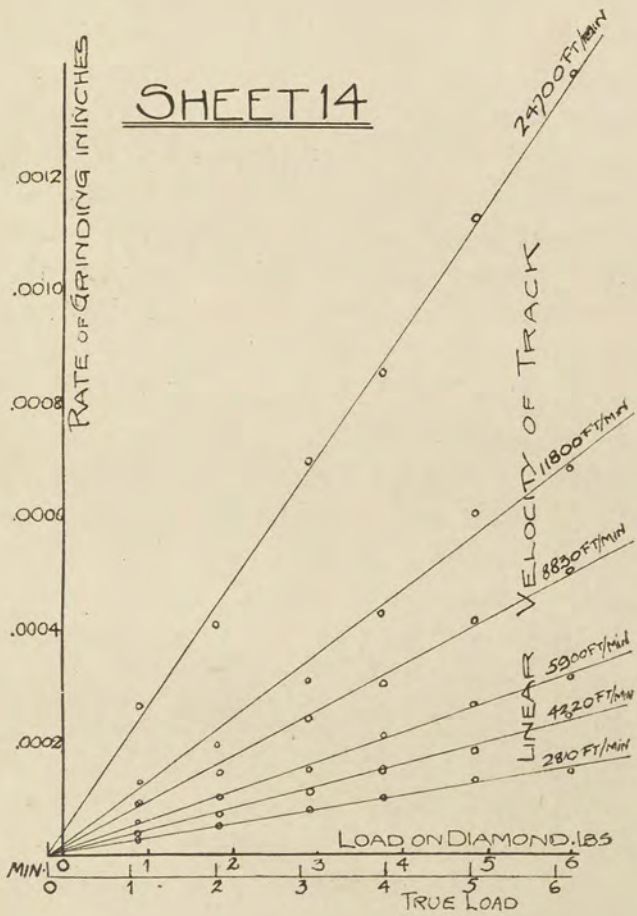
N = speed of wheel in revolutions per minute

d = diameter of track in inches.

The curve of the rate of grinding against the linear speed at constant loads is plotted on sheet 13. They are proportional.

If now we plot the rate of grinding against the load at constant linear speeds


SHEET 13
ADDED LOAD
5.10 lbs
3.96 lbs
2.88 lbs
2.08 lbs
0.94 lbs
0 lbs
RATE OF GRINDING IN INCHES
.0012
.0010
.0008
.0006
.0004
.0002
0
6000
12000
18000
24000 FT
LINEAR VELOCITY OF TRACK


SHEET 14
RATE OF GRINDING IN INCHES
.0012
.0010
.0008
.0006
.0004
.0002
LINEAR VELOCITY OF TRACK
24700 FT/MIN
11800 FT/MIN
8830 FT/MIN
5900 FT/MIN
4320 FT/MIN
2810 FT/MIN
LOAD ON DIAMOND. LBS
MIN. LOAD
0 1 2 3 4 5 6
0 1 2 3 4 5 6
TRUE LOAD

of grinding (sheet 14), we see that these two variables are proportional, the curve is a straight line. It will be seen that a zero error was made, an error in the weight of the dop and holder: they were weighed when in position in the carrier, and no account was taken of the friction round the spindle; when running however, the vibration nullifies the effect of friction, and the zero load is correspondingly increased to 1.15 lbs. which is the full weight, as was found afterwards.

It appears thus that if:

R = rate of grinding of diamond in inches per minute

D = diameter of grinding track in feet

N = speed of rotation of the grinding wheel in R.P.M.

W = load on the diamond in pounds

C = in a constant

then $R = C \pi N D W$

at constant area of the facet ground.

The trial now studied gives for C the following value:

$$C = \frac{R}{\pi N D W}$$

Taking on sheet 14 the points on the curves at, say, 6 lbs. true load (corrected scale), we obtain:

At 24700 ft. per minute $C = \frac{0.00134}{6 \times 24700} = ,907 \times 10^8$

At 11800 ft. per minute $C = \frac{0.00066}{6 \times 11800} = ,933 \times 10^8$

At 8830 ft. per minute $C = \frac{0.00048}{6 \times 8830} = ,906 \times 10^8$

At 5900 ft. per minute $C = \frac{0.00032}{6 \times 5900} = ,904 \times 10^8$

At 4220 ft. per minute $C = \frac{0,0023}{0 \times 4220} = ,908 \times 10^8$

At 2810 ft. per minute $C = \frac{0,0015}{0 \times 2810} = ,891 \times 10^8$

This gives as average value for C

$$C = ,908 \times 10^8$$

Prism 2

The next prism, whose results are given below, although not the second one in point of time to be experimented upon, is yet given here because of certain peculiarities which are very noteworthy and of great consequence, and which were shown most distinctly in this particular instance.

Dimensions of prism

$h_1 = \cdot 066''$ $h_2 \cdot 078 = h_3 = \cdot 079''$ area $= \cdot 00318$ sq inches.

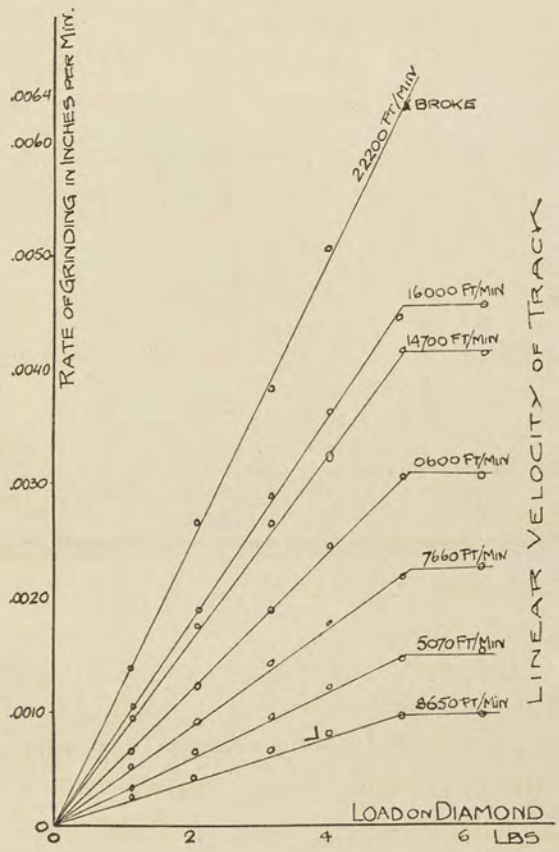
Table of rates of grinding.

TABLE 12.

	Added Load lbs.	0	0.94	2.02	2.88	3.96	5.10	Linear velocity of grinding track feet per minute
Speed R.P.M.	Total Load lbs. / Track diameter (inch)	1.15	2.09	3.17	4.05	5.11	6.25	
2150	$6\frac{1}{2}''$	00024	00040	00064	00079	00097	00099	3650
	9″	00032	00064	00092	00199	00145	00152	5070
4500	$6\frac{1}{2}''$	00052	00092	00140	00180	00217	00224	7600
	9″	00064	00120	00197	00240	00300	00305	10600
6250	$6\frac{1}{2}''$	00064	00124	00198	00249	00305	00310	10630
	9″	00095	00176	00264	00320	00416	00409	14700
9420	$6\frac{1}{2}''$	00104	00188	00283	00361	00453	00453	16000
	9″	00140	00260	00383	00505	00627	broke	22200

If (sheet 15) the curves of rates of grinding against load are plotted at the various linear velocities, it will be seen that, at first, the rate of grinding increases as the load and proportionately to the load, but that at approximately the load of 5.11 lbs. a further increase of the load brings no increase in the rate of grinding: the curve suddenly turns from a straight inclined to a straight horizontal line.

If we calculate the value of C from the part of the curve where the rate of grinding


RATE OF GRINDING IN INCHES PER MIN.
.0064
.0060
.0050
.0040
.0030
.0020
.0010
0
0
2
4
6 LBS
LOAD ON DIAMOND
LINEAR VELOCITY OF TRACK
22200 FT/MIN
BROKE
16000 FT/MIN
14700 FT/MIN
0600 FT/MIN
7660 FT/MIN
5070 FT/MIN
8650 FT/MIN

SHEET 15.

and the load are proportional, we obtain (from point on curves on sheet 15):

$$C = \frac{R}{\pi N D W}$$

$= $ respectively

5.59×10^8	at	22200 ft.	per	minute
5.43×10^8	,,	16000 ,,	,,	,,
5.58×10^8	,,	14700 ,,	,,	,,
5.60×10^8	,,	10600 ,,	,,	,,
5.50×10^8	,,	7660 ,,	,,	,,
5.62×10^8	,,	5070 ,,	,,	,,
5.25×10^8	,,	3650 ,,	,,	,,

This gives as average value, $C = 5.50 \times 10^8$.

We find for C a value much larger than in the case of Prism 1. As the only difference between the two experiments was in the area of the prisms tested, we have to find the relation between C and the area.

Now $$\frac{C_2}{C_1} = \frac{5.50 \times 10^8}{.908 \times 10^8} = 6.07$$

also $$\frac{a_1}{a_2} = \frac{.01738}{.00318} = 5.47$$

It appears thus that C varies inversely as the area tested. We may say here that this was proved to be true by the further experiments and that, if

$$C = \frac{K}{A}$$

$$R = K \pi N D \frac{W}{A}$$

where

$\pi N D =$ linear velocity of track

$\frac{W}{A} =$ pressure en facet

i. e. ALL OTHER THINGS BEING EQUAL THE RATE OF GRINDING IS PROPORTIONAL TO THE LINEAR VELOCITY OF THE GRINDING TRACK AND TO THE INTENSITY OF PRESSURE BETWEEN THE GRINDING WHEEL AND THE FACET GROUND.

This law holds good up to a certain value of the pressure, which the trials with prism no 2 put at about 1600 lbs. per square inch.

It was found very difficult to determine that critical value of the pressure with accuracy, as the prisms tested could not stand such a great pressure, but split as soon as they were loaded along one of the cleavage planes. This splitting was, no doubt, facilitated by the very slight but unavoidable tremor of the grinding wheel. The four speciments which resisted gave the following values for the critical pressure.

Prism	no. 2	1620	lbs.	per	sq.	inch.
,,	no. 7	1450	,,	,,	,,	,,
,,	no. 11	1360	,,	,,	,,	,,
,,	no. 15	1520	,,	,,	,,	,,

RESULTS OF PRISMS TESTED

The following are the values of C and K obtained for all the prisms experimented upon. Altogether 24 prisms were ground, four rhomboïcal and twenty triangular in cross-section. The dimensions measured from the specimens are given below, as well as the corresponding areas as obtained from large-scale drawings. The dimensions are: in the case of a rhombus, the perpendicular distance between the two opposite surfaces; in the case of a triangle the three heights. It may be added here that the angle between two cleavage planes is always $70\frac{1}{2}^\circ$ (or $109\frac{1}{2}^\circ$) in a diamond.

TABLE 13.

Prism no.	Cross-Section of prism	h_1	H_2	h_3	Area	C $\times 10^8$	K = CA $\times 10^{10}$
1	Parallelogram	.110	.148	—	.01738	0.908	1.58
2	Triangle	.066	.078	.079	.00308	5.50	1.70
3	Triangle	.075	.088	.089	.00400	4.12	1.65
4	Parallelogram	.100	.108	—	.01140	1.51	1.72
5	Triangle	.068	.080	.057	.00328	2.49	0.82
6	Triangle	.067	.078	.077	.00319	5.11	1.63
7	Triangle	.065	.076	.077	.00302	5.44	1.64
8	Triangle	.062	.072	.074	.00273	6.11	1.67
9	Triangle	.060	.070	.071	.00256	6.40	1.70
10	Parallelogram	.062	.068	—	.00435	3.91	1.70
11	Triangle	.058	.068	.067	.00239	7.20	1.72
12	Triangle	.057	.067	.065	.00223	6.61	1.57

Prism no.	Gross-Section of prism	h.	H_2	h_3	Area	C $\times 10^8$	K=CA $\times 10^{10}$
13	Triangle	.054	.055	.063	.00207	7.96	1.65
14	Triangle	.052	.060	.061	.00192	9.19	1.76
15	Triangle	.048	.035	.057	.00164	7.20	1.18
16	Triangle	.045	.052	.054	.00144	10.55	1.52
17	Triangle	.045	.053	.051	.00144	12.23	1.76
18	Triangle	.044	.052	.051	.00138	12.99	1.79
19	Triangle	.044	.050	.052	.00138	12.08	1.67
20	Triangle	.044	.051	.042	.00138	11.60	1.60
21	Parallelogram	.054	.057	—	.00319	5.09	1.62
22	Triangle	.040	.047	.045	.00114	10.20	1.16
23	Triangle	.040	.046	.035	.00108	14.22	1.54
24	Triangle	.040	.046	.042	.00104	15.50	1.61

Average value of $K = 1.66 \times 10^{-10}$

It will be seen that the values of K are approximately constant und that therefore the assumption made before

$$\left(\text{i. e. that } C = \frac{K}{A}\right)$$

was justified: the rate of grinding is proportional to the intensity of pressure on the area ground. If we omit the value of K given by prisms 5, 15 and 22, which are obviously abnormally small (for reasons similar to those mentioned at the end of Part 1), the total variation in K amounts to from about 8% for the larger stones to 15% for the smaller i. e. from 4 to 8% on either side of the mean. The remarks at the end of Part 1 apply here also: this

amount of variation must be considered very small if we bear in mind that diamond is neither homogeneous nor always uniform in structure.

The average value of K (neglecting those values 5, 15 and 22), is given at the bottom of the column: it is 1.66×10^{-10} in inch and minute units.

Let us now compare the quantitative value obtained above with the values obtained in Part 1.

Taking the above value of K, we may calculate the time taken for grinding a stone in the plane and direction considered under any conditions of speed, load and diameter. Let us take, say, an area of $0.1'' \times 0.1'' = 0.01$ square inches under a load of 5.2 lbs., at a speed of 2100 R. P. M. and a diameter of $10\frac{1}{2}''$.

Then

The rate of grinding

$$R = K\pi ND\frac{W}{A}$$

$$= 1.66 \times 10^{-10} \times 2100 \times \frac{10\frac{1}{2}}{12} \times \frac{5.2}{0.01}$$

$$= .000498 \text{ inches per minute}$$

From this we can deduce the weight of diamond ground per minute

Volume $= .000498 \times .01 = .00000498$ cubic inches.

Now the density of diamond is 3.52, i. e., 1 cubic cm. of diamond weight 3.52 grams or $3.52 \times 5 = 17.60$ carats.

Therefore,

Weight ground per minute

$= .00000498 \times 17.6 \times 2.54^3$
$= .0000817 \times 17.6$
$= .00144$ cts.

Part 1 gives us as weight ground per minute under the same conditions of load, speed and diameter (sheet 1),

Weight ground per minute $= 0.00627$ cts.

A great discrepancy between the rates of grinding will be noticed: the ordinary stones were ground 4.35 times more quickly than the prisms under the same conditions of loading, speed of grinding wheel, and diameter of grinding track.

What is this difference due to? An investigation showed that the reason is both fairly obvious and, in the circumstances, unavoidable:

The prisms were introducted to have a constant area ground throughout the set of experiments performed on one stone: the area of cross-section being constant in a prism, the end was achieved by placing the prism perpendicularly to the plane of grinding, this position being selected because it corresponds to the plane ground most frequently in practice and because of the greater loading allowed by this position. But then, all the faces of the prism are perpendicular to the plane of the grinding wheel, and there is a sharp edge (with an angle of 90°) at the intersection of each face with the facet ground.

This edge is in contact with the grinding wheel and would act as a cutting tool if the facet ground did not prevent it from penetrating into the metal. As it is, it acts as a kind of plane, and although not planing the metal away, yet its contact with the wheel is sufficiently intimate to prevent the diamond powder used for grinding from getting into all the pores of the cast iron: it only gets into the deeper ones and is

removed by the edge from the shallow ones: so that grinding proceeds with a relatively small amount of powder. If more of the diamond powder is added to the wheel, it is scraped away by the sharp edge of the prism.

Whereas in an ordinary stone, there is no sharp edge; on the contrary, the material of the stone and the wheel approach very gradually until they touch at the facet ground, and any powder added is wedged into the pores of the grinding wheel until they are all filled.

This explains the discrepancy in the quantitative results. But this discrepancy does not affect in the least the fundamental laws established in the preceding pages (it only emphasizes the importance to have the pores well filled with powder).

The fundamental laws hold: for the *same facet*, the rate of grinding, other things being equal, is directly proportional to the linear velocity of the grinding track and to the intensity of pressure on the facet ground, up to a certain critical value for that intensity, when a further increase in pressure does not affect the rate of grinding.

GROUP 2:
VARIABLE INCLINATIONS

After the conclusion of the preceding group of experiments, i. e. the grinding of prisms placed vertically in the plane of the grinding wheel, the same method was applied in cases where the plane of the facet ground is obliquely inclined to the axis of the prism. By inclining the prism to any desired amount by means of the arcuate mounting, and by rotating it about its own axis by rotating the dop in this manner (the prism being placed co-axially with the dop) any desired facet could be subjected to the grinding action of the wheel. The facets selected for thorough testing were of the fundamental types and intermediate facets, i. e. those corresponding to:

1° a facet on a face of the octahedron.

2° a facet on an edge of the octahedron and equally inclined to the faces meeting at that edge.

3° a facet on a solid angle of the octahedron, cutting off equal lengths from the four similar edges forming that solid angle,

and facets intermediate between the first and the second, and the second and the third.

Or to put it in terms used in the diamond industry.

1° The table of a 3-point or was.

2° The table of a 2-point.

3° The table of a 4-point.

MEASUREMENT OF THE DIRECTION AND ANGLE OF GRINDING: The direction of grinding was measured in degrees, as given by the relative displacement of a scale and a pointer placed on the arm and on the outer micrometer sleeve. The scale was graduated so as to read zero when the arcuate

mounting points in the same direction as the arm. Supposing, we remove the arm from the stand and hold it with the facet facing us, then the divisions read positively from 0″ to 360° for counter - clockwise rotation. As an illustration and an explanation the two annexed photographs show the position of the stone at 115° and at 315°.

The divisions on the arcuate mounting read zero when the dop is vertical (as shown in fig. 7) and give the inclination from the vertical in degrees. The position at 45° is shown in fig. 8.

Setting of the prisms. To obtain the values of K for the desired facets on the prisms, these had to be set in two different ways. One manner of setting is shown on fig. 7: the sawn face of the prism (i. e. the broader face) is set parallel to the plane of symmetry of the arcuate mounting (as mentioned in the description of the machine, delicate adjustment of this setting can be made by means of a screw). The photograph also shows how the claws grip the prism

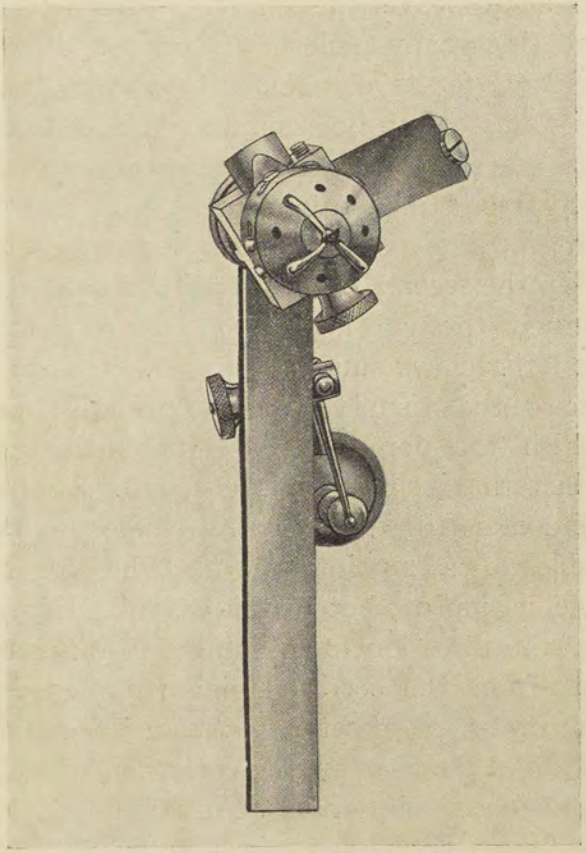


FIGURE 7

Inclination = 315°

so as to leave one side free for experimenting at any angle of inclination. By this setting, facets corresponding to the table of a 2-point can be ground - (inclination 0°) also facets corresponding to the table of a 4 - points (inclination 45°) and any desired intermediate position.

In the second type of setting, the dop is turned through 90° about its own axis and the claws suitably altered. The sawn face of the prism is parallel to the axis about which the dop and the dop-holder turn when the inclination is changed. By this kind of setting facets corresponding to the table of a 2-point can also be ground (inclination 0°) but in this case all readings for the direction of grinding will differ by 90° from the corresponding readings will the first type of setting. At an inclination of $35^1/_4$° the facet ground corresponds to the table of a 3-point or was. Any desired intermediate position can of course be obtained by suitably choosing the inclination.

For any of the inclinations and settings, the corresponding values of K were found

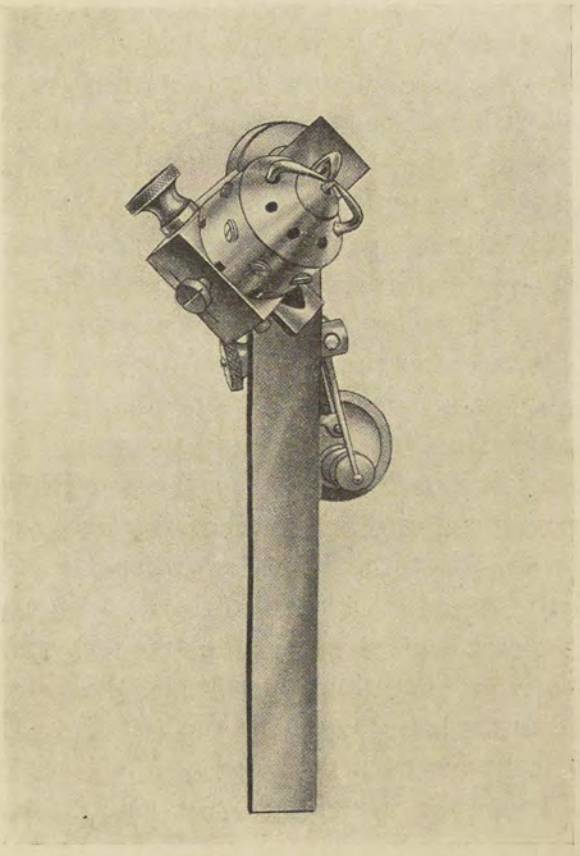


FIGURE 8

Inclination = 115°

not only for each facet, but also for all directions of grinding on that facet: this was obtained by rotating the whole of the dop with mounting, arcuate carrier, spindle and micrometer sleeves about a vertical axis (by means as given in the description of the special machine) the position of the arm surrounding the outer sleeve being unaltered. The facet ground was turned in that way after the conclusion of each set of readings by one thirty-second of a circumference (i. e. by $11^1/_4°$) and the value of K was calculated for each of these positions.

In calculating the value of K account was taken of the fact that when the axis of the prism is oblique to the area ground, that area is greater than the area of perpendicular cross-section, the ratio between these two areas being equal to the secant of the angle between them.

The tables given below and the corresponding curves (sheets 16 to 21) are the result of numerous experiments as described above, fifty-nine stones being ground to that purpose. It is to be emphasized here

that the figures given in the tables and plotted on the sheets are derived from these results by averaging these and making them symmetrical: it was found impossible in practice to grind a facet corresponding *absolutely* with the desired position as defined on page 91: there was always some slight inclination one way or the other, so that the plane of the grinding wheel was not quite symmetrical with respect to the axis of crystallization of the diamond; as a consequence there was always a corresponding asymmetry in the curves, one of the peaks (sheets 16, 19, 20, 21) being lower than the other sometimes by as much $^1/_3$ or in the case of the 3-point (sheet 18) one or even two peaks disappearing altogether, while the remaining increased somewhat.

The curves and tables given have thus been built up from the averages of the results, on the assumption that ideal facets absolutely symmetrical with respect to the crystallisation were ground, so that the peaks on a curve corresponding to similar directions are of the same height.

SETTING I.

(Axis of rotation of dop and holder for variable inclinations is parallel to sawn face of prism tested.)

A. Inclination = 0.

Facet ground corresponds to an edge of the octahedron i. e. to the table of a 2-point.

TABLE 14 (sheet 16).

Direction of grinding	Value of $K \times 10^{10}$	Direction of grinding	Value of $K \times 10^{10}$
0	0		
$11\frac{1}{4}$	0	$191\frac{1}{4}$	0
$22\frac{1}{2}$	0.03	$202\frac{1}{2}$	0.03
$33\frac{3}{4}$	0.10	$213\frac{3}{4}$	0.10
45	0.20	225	0.20
$56\frac{1}{4}$	0.38	$236\frac{1}{4}$	0.38
$67\frac{1}{2}$	0.69	$247\frac{1}{2}$	0.69
$78\frac{3}{4}$	1.38	$258\frac{3}{4}$	1.38
90	1.72	270	1.72
$101\frac{1}{4}$	1.38	$281\frac{1}{4}$	1.38
$112\frac{1}{2}$	0.69	$292\frac{1}{2}$	0.69
$123\frac{3}{4}$	0.38	$303\frac{3}{4}$	0.38
135	0.20	315	0.20
$146\frac{1}{4}$	0.10	$326\frac{1}{4}$	0.10
$157\frac{1}{2}$	0.03	$337\frac{1}{2}$	0.03
$168\frac{3}{4}$	0	$348\frac{3}{4}$	0
180	0	360	0

The above table was plotted on sheet 16.

B. Inclination = 20°.

Facet intermediate between the edge and the face of an octadedron, i. e. between the table of a 2-point and the table of a 3-point or was.

SHEET 16
0.01 × Y
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 225 270 315 360
DIRECTION OF GRINDING: DEGREES
INCLINATION = 0°
7*

SHEET 17
INCLINATION = 20°
DIRECTION OF GRINDING: DEGREES
0
20
40
60
80
100
120
140
160
180
225
270
315
360
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
I₀/I × Y

SHEET 18
INCLINATION = 35½°
0 0 1 0 × Y
1.0
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 225 270 315 360
DIRECTION OF GRINDING DEGREE

TABLE 15 (sheet 17).

Direction of grinding	Value of K × 10^{10}	Direction of grinding	Value of K × 10^{10}
0	0		
$11\frac{1}{4}$	0	$191\frac{1}{4}$	0
$22\frac{1}{2}$	0	$202\frac{1}{2}$	0
$33\frac{3}{4}$	0.02	$213\frac{3}{4}$	0
45	0.08	225	0
$56\frac{1}{4}$	0.20	$236\frac{1}{4}$	0
$67\frac{1}{2}$	0.51	$247\frac{1}{2}$	0
$78\frac{3}{4}$	1.04	$258\frac{3}{4}$	0
90	1.33	270	0
$101\frac{1}{4}$	1.04	$281\frac{1}{4}$	0
$112\frac{1}{2}$	0.51	$292\frac{1}{2}$	0
$123\frac{3}{4}$	0.20	$303\frac{3}{4}$	0
135	0.08	315	0
$146\frac{1}{4}$	0.02	$326\frac{1}{4}$	0
$157\frac{1}{2}$	0	$337\frac{1}{2}$	0
$168\frac{3}{4}$	0	$348\frac{3}{4}$	0
180	0	360	0

The above table was plotted on sheet 17.

C. Inclination = $35\frac{1}{4}°$.

Facet ground corresponds to the face of an octahedron or to the table of a 3-point or was.

TABLE 16 (sheet 18).

Direction of grinding	Value of K × 10^{10}	Direction of grinding	Value of K × 10^{10}
0	0	90	0.140
$11\frac{1}{4}$	0	$101\frac{1}{4}$	0.064
$22\frac{1}{2}$	0	$112\frac{1}{3}$	0.020
$33\frac{3}{4}$	0	$123\frac{3}{4}$	0
45	0	135	0
$56\frac{1}{4}$	0	$146\frac{1}{4}$	0
$67\frac{1}{2}$	0.020	$157\frac{1}{2}$	0
$78\frac{3}{4}$	0.064	$168\frac{3}{4}$	0

Direction of grinding	Value of K × 10^{10}
180	0
$191\frac{1}{4}$	0.020
$202\frac{1}{2}$	0.060
$213\frac{3}{4}$	0.116
225	0.032
$236\frac{1}{4}$	0
$247\frac{1}{2}$	0
$258\frac{3}{4}$	0
270	0

Direction of grinding	Value of K × 10^{10}
$281\frac{1}{4}$	0
$292\frac{1}{2}$	0
$303\frac{3}{4}$	0
315	0.032
$326\frac{1}{4}$	0.116
$337\frac{1}{2}$	0.060
$348\frac{3}{4}$	0.020
360	0

The above table is plotted on sheet 18.

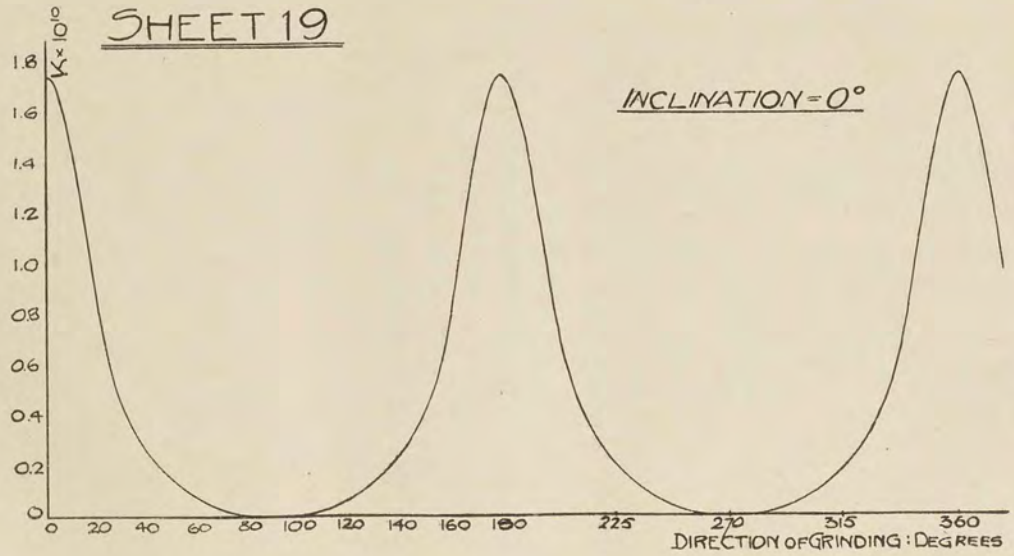
SETTING 2.

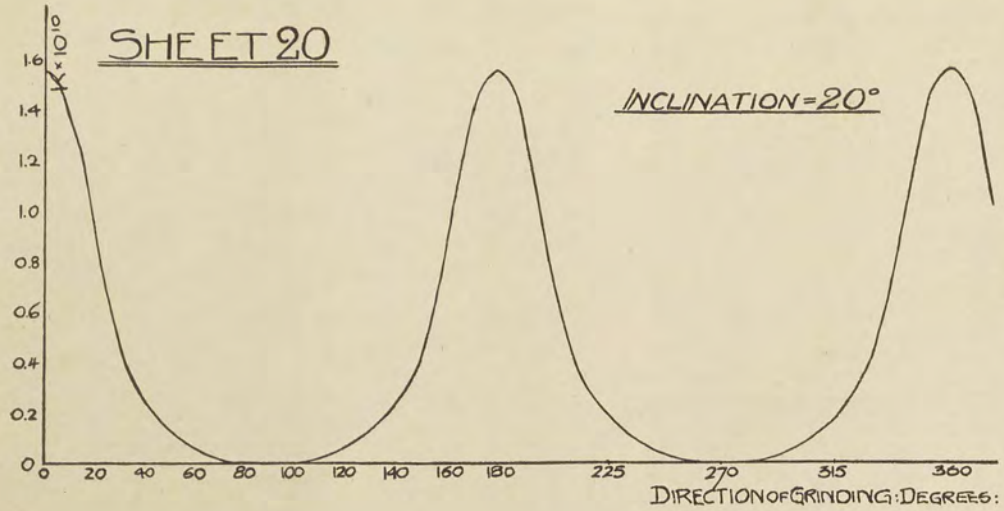
(Axial plane of arcuate mounting is parallel to sawn face of prism tested.)

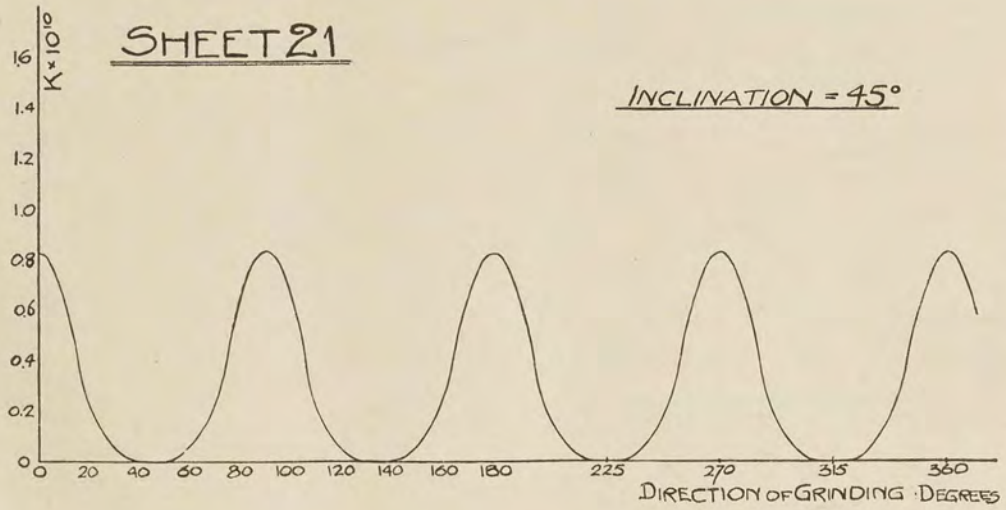
A. Inclination = 0°.

The facet ground correspond to an edge of the octahedron, i. e. to the table of a 2-point.

The values of *W* at the various directions of grinding are the same (for similar directions) as those given in table 14 and plotted on sheet 16 except that owing to the rotation of 90° given to the dop about its own axis, there will be a difference of 90° in the values of the direction of grinding and a corresponding displacement of the curve along its base. The table is therefore not given, but the curve is annexed on sheet 19.


SHEET 19
K × 10^10
INCLINATION = 0°
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 225 270 315 360
DIRECTION OF GRINDING : DEGREES


SHEET 20
INCLINATION = 20°
χ × 10¹⁰
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 225 270 315 360
DIRECTION OF GRINDING: DEGREES:


SHEET 21
INCLINATION = 45°
K × 10¹⁰
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 225 270 315 360
DIRECTION OF GRINDING · DEGREES

B. Inclination = 20°.

Facet intermediate between the edge and the solid angle of an octahedron, i. e. between the table of a 2-point and the table of a 4-point.

TABLE 17 (sheet 20).

Direction of grinding	Value of K × 10^{10}	Direction of grinding	Value of K × 10^{10}
0	1.56	$191\frac{1}{4}$	1.33
$11\frac{1}{4}$	1.33	$202\frac{1}{2}$	0.71
$22\frac{1}{2}$	0.71	$213\frac{3}{4}$	0.34
$33\frac{3}{4}$	0.34	225	0.18
45	0.18	$236\frac{1}{4}$	0.08
$56\frac{1}{4}$	0.08	$247\frac{1}{2}$	0.02
$67\frac{1}{2}$	0.02	$258\frac{3}{4}$	0
$78\frac{3}{4}$	0	270	0
90	0	$281\frac{1}{4}$	0
$101\frac{1}{4}$	0	$292\frac{1}{2}$	0.02
$112\frac{1}{2}$	0.02	$303\frac{3}{4}$	0.08
$123\frac{3}{4}$	0.08	315	0.18
135	0.18	$326\frac{1}{4}$	0.38
$146\frac{1}{4}$	0.34	$337\frac{1}{2}$	0.71
$157\frac{1}{2}$	0.71	$348\frac{3}{4}$	1.33
$168\frac{3}{4}$	1.33	360	1.56
180	1.56		

The above table was plotted on sheet 20.

C. Inclination = 45°.

This facet corresponds to the solid angle of the octahedron i. e. to the table of a 4-point.

TABLE 18 (sheet 21).

Direction of grinding	Value of K × 10^{10}	Direction of grinding	Value of K × 10^{10}
0	0.82		
$11\frac{1}{4}$	0.62	$191\frac{1}{4}$	0.62
$22\frac{1}{2}$	0.18	$202\frac{1}{2}$	0.18
$33\frac{3}{4}$	0.03	$213\frac{3}{4}$	0.03
45	0	225	0
$56\frac{1}{4}$	0.03	$236\frac{1}{4}$	0.03
$67\frac{1}{2}$	0.18	$247\frac{1}{2}$	0.18
$78\frac{3}{4}$	0.62	$258\frac{3}{4}$	0.62
90	0.82	270	0.82
$101\frac{1}{4}$	0.62	$281\frac{1}{4}$	0.62
$112\frac{1}{2}$	0.18	$292\frac{1}{2}$	0.18
$123\frac{3}{4}$	0.03	$303\frac{3}{4}$	0.03
135	0	315	0
$146\frac{1}{4}$	0.03	$326\frac{1}{4}$	0.03
$157\frac{1}{2}$	0.18	$337\frac{1}{2}$	0.18
$168\frac{3}{4}$	0.62	$348\frac{3}{4}$	0.62
180	0.82	360	0.82

The above table was plotted on sheet 21.

It appears at once that the most important part of the curve from a practical point of view, is the height of the peak, for this determines the maximum speed of grinding in any position. It will be seen that the peak occurs at a constant direction of grinding for any inclinations in one setting.

Experiments were thus made with both settings, to determine the value of K at variable inclinations and at the constant optimum direction of grinding.

The results obtained are as follows (the

remarks made previously as regards the facet holding good in this case):

Setting 1 Direction of grinding = 90°

TABLE 19 (sheet 23).

Inclination	Value K × 10^{10}
—10	0
—5	1.22
0	1.74
5	1.71
10	1.63
15	1.51
20	1.33
25	1.07
30	0.73
35¼	0.14
40	0
45—55	0

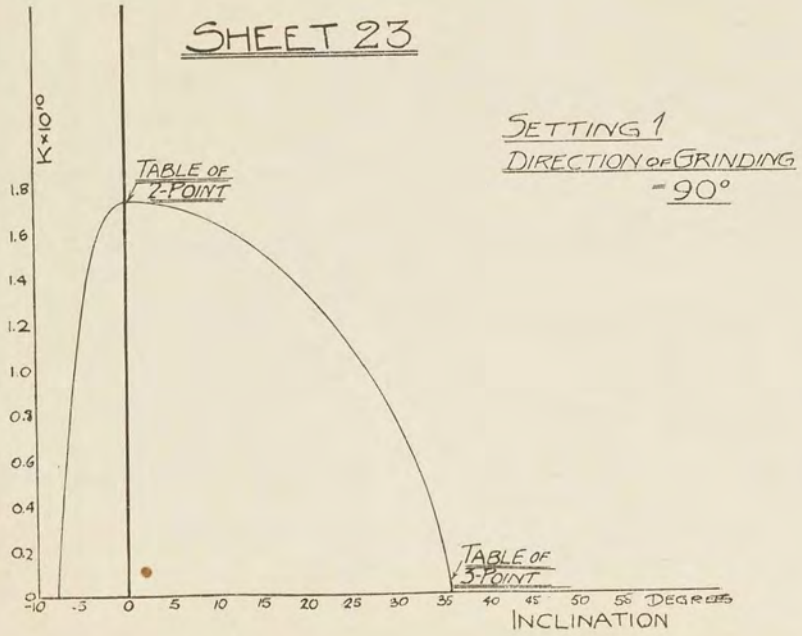
The values were plotted on sheet 23.

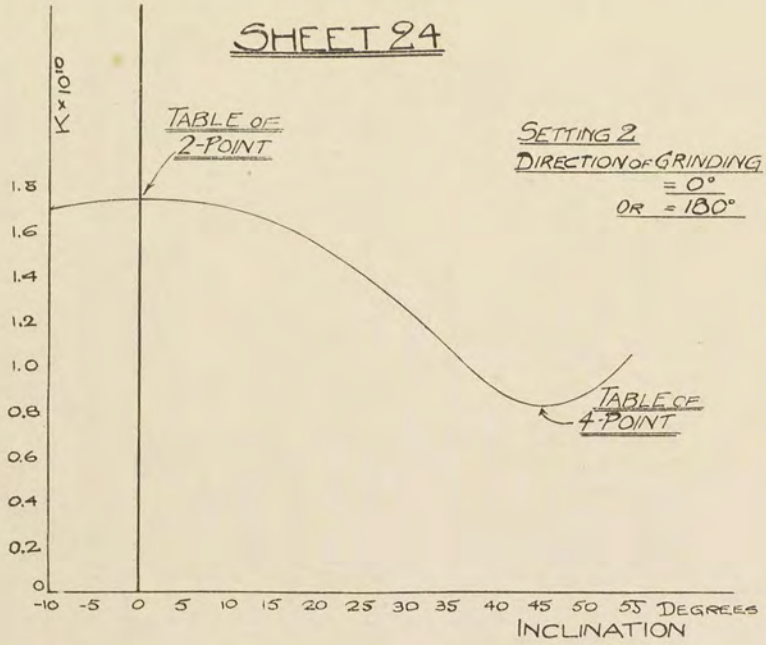
Setting 2 Direction of grinding = 0° or 180°

TABLE 20 (sheet 24).

Inclination	Value K × 10^{10}
—10	1.70
—5	1.73
0	1.74
5	1.73
10	1.70
15	1.64
20	1.56
25	1.40
30	1.24
35	1.06
40	0.89
45	0.82
50	0.89
55	1.06

These values were plotted on sheet 24.


SHEET 23
SETTING 1
DIRECTION OF GRINDING
= 90°
K×10^10
TABLE OF 2-POINT
TABLE OF 3-POINT
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
DEGREES
INCLINATION


SHEET 24
K x 10^10
TABLE OF 2-POINT
SETTING 2
DIRECTION OF GRINDING
= 0°
OR = 180°
TABLE OF 4-POINT
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 DEGREES
INCLINATION

ANALYSIS OF THE RESULTS OBTAINED IN THIS GROUP OF EXPERIMENTS

The most remarkable characteristic of the curves on sheets 16 to 21 is their exceedingly peaky outline, and the sharpness of the peaks. This illustrates in a striking manner the great importance of the correct placing of the stone upon the grinding wheel: for each facet there is one correct direction of grinding, and *only one.* (In practice, as noted before, the heights of the peaks are never equal owing to the asymmetry of the facet with respect to the axis of crystallisation.) A difference of a few degrees on either side of the optimum direction of grinding decreases the value of K and the corresponding rate of grinding very considerably.

SETTING 1.

This setting enables us to grind a facet on the edge of the octahedron, one on the face of the octahedron, or any desired intermediate facet.

Let us consider that we are grinding the table of a 2-point, and that we are changing the direction of grinding, and at the same time, but very much more slowly, the inclination of the stone, so that the facet ground very gradually changes from the table of a 2-point to the „soft" corner of a 2-point (i. e. the table of a 3-point).

(Sheets 16, 17, 18 and 23.)

Then, for the table of a 2-point, we reach a steep maximum when the direction of grinding is perpendicular to the edge of the octahedron. As the direction of grinding changes, the rate of grinding decreases very rapidly, at first and then more slowly to reach zero when the edge is parallel to the direction of grinding; it increases then, slowly at first and thereupon very steeply, to reach a second maximum when the direction of grinding is again perpendicular

to the edge. If the rotation proceeds, the rate of grinding again decreases, as before, to a second zero and returns to the first maximum.

As now the inclination changes the two maxima occur for the same directions of grinding. One of them however, decreases slowly, and the other very rapidly; to explain which is the first and which the second let us consider the octahedron placed on the grinding wheel with an edge in the plane of the wheel and perpendicularly to the direction of grinding; as the inclination varies, one face approaches the grinding wheel and the other becomes separated from it: when the face nearer the wheel is placed "upstream" i. e. facing the direction of rotation of the grinding track, the maximum decreases slowly (see sheet 23, positive part of curve). When the face nearer the wheel is placed "downstream" and the other "upstream" the maximum decreases very rapidly as the inclination varies (sheet 23, negative of curve) and with an inclination of about 8° it has absolutely disappeared.

Sheet 17 shows the nature of the curve at an inclination of 20°; one peak only is left in the curve.

As the inclination increases, the maximum of that peak decreases at an increasing rate and the curve showing that decrease (sheet 23) becomes very steep; when an inclination of $35\frac{1}{4}°$ is reached, i. e. when the face of the octahedron which was approaching the grinding wheel is in the plane of the wheel, the rate of grinding is zero for any direction of grinding.

It will be noted that sheet 18 shows three very small peaks in directions of grinding distant from each other by 120°. This is because it was found impossible to obtain in practice a facet *absolutely* coincident with the face of the octahedron (i. e. with the cleavage plane). There was always some slight unavoidable inclination from the side ofone or two of the edges of the face. As the curve for the value of the maximum (sheet 23) is exceedingly steep at that point, even the very slightest inclination will give an appreciable rate of cutting.

But if it is attempted to polish, say, the collet of a rose, which is generally a cleavage plane, it will be found that the grinding proceeds very slowly and that the nearer an approach is made to the true cleveage plane, the more difficult grinding becomes. If by some chance the stone is set exactly with the cleavege plane in the plane of the grinding wheel, the stone may be left for days on the wheel without any appreciable progress being made.

This emphasizes the need to give a slight inclination to the table of a 3-point whenever possible and to make that inclination as large as possible.

SETTING 2.

In this setting the table of a 2-point, the table of a 4-point, and any desired intermediate facets may be ground.

Let us consider that we are grinding the table of a 2-point, and that we are changing the direction of grinding, and at the same time, but very much more slowly, the inclination of the stone, so that the facet

ground very gradually changes from the table of a 2-point to the table of a 4-point. (Sheets 19, 20, 21, and 24.)

As noted previously, sheet 19 is the same as sheet 16 with the curve shifted 90° along its base: The maxima occur for the same relative positions of the stone and the grinding wheel, but the stone being turned through 90°, the value of the direction of grinding differs by 90°.

If thus, starting from the table of a 2-point, we increase the inclination slowly towards the table of a 4-point, the optimum directions of grinding remain unaltered but the height of the peaks decreases at an increasing rate, both peaks decreasing by the same amount; when an inclination of about 37° is reached, the rate of decrease diminishes, and the value of the maximum rate of grinding reaches a minimum at an angle of inclination of 45° corresponding to the table of a 4-point or a facet placed symmetrically on the solid angle ot the octahedron. *At* that inclination, two more peaks appear, corresponding to the edges

of the octahedron which cross the edge considered at right angles at the solid angle. These two supplementary peaks seem to be peculiar to that position and to its immediate neighbourhood. At inclinations of 40° or 50° only traces of their presence remain.

5. THEORY OF THE STRUCTURE OF DIAMOND-GRINDING

Diamond being a crystal, it is to crystallography that we look to provide us with an explanation of the phenomena which we have examined in the preceding parts. There is no explanation forthcoming. It is true that mention is made in most textbooks that there are differences of hardness on different faces of the same crystal (as, for example, in the case of calcite) or that there are differences of hardness along different directions in the same face (as in the case of rock-salt). But no explanation is given as to why this should be so.

When we turn to the fundamentals of the several theories of crystallography, and

try to find an explanation by reasoning from first principles, we find that most theories are useless. The mathematical treatment of the subject based upon the atomic theory of matter, as is the works of Bravais, Sohncke and others, did not prove of any use. If we turn to Haüy's theory of the structure of crystals, we find it very suggestive; Haüy found that a crystal could be reduced by cleavage to a kernel which has always exactly the same shape and the same angles; he further imagined that the crystal could be divided into a great number of such kernels, too small to be perceived separately, although still of the same definite size and shape.

Conversely he held that by suitable arrangement of these exceedingly small kernels it must be possible to build up the original crystal or one having any of the forms presented by the mineral.

The most serious objection to this theory is that when the cleavage-form is an octahedron, as in the case of diamond, it was found impossible to arrange the

constituent bricks (as they are called) so as to fill up space completely; if it be required that the little octahedra be parallel to each other and have their faces in directions parallel to the cleavage planes of the resulting crystal, then it is found that they have to be arranged with only their edges in contact, and it is difficult to see that such a skeleton-like structure would not collapse immediately.

This objection is very grave and unanswerable by Haüy's theory. But there is a graver objection still, which appears not to have been noticed in the comments on Haüy's theory. And that is, that in the case of an octahedron, it is impossible to divide the crystal into bricks of the same definite size and shape: there is no *one* kernel in this case: there are *two:*

For it is impossible to cleave an octahedron into smaller octahedra without the creation of tetrahedra. Similarly it is impossible to cleave a tetrahedron into smaller tetrahedra without the creation of octahedra. The octahedron and the tetrahedron have thus

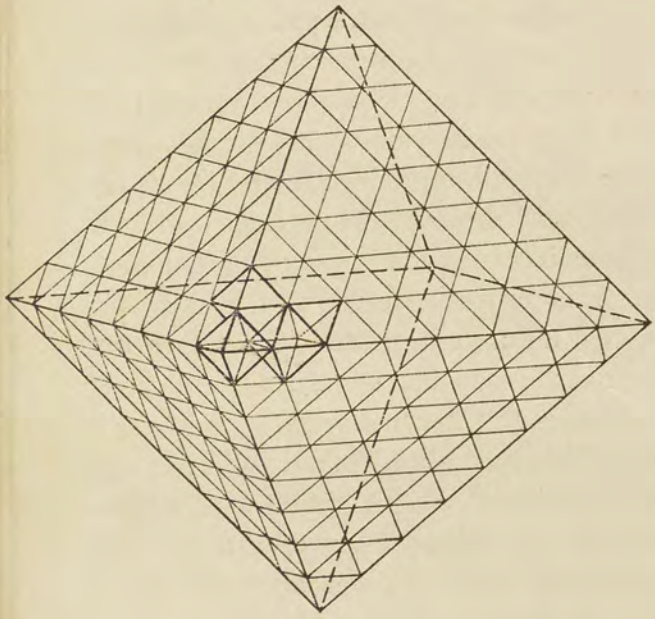
both to be considered as having *two* different types of bricks, minute octahedra and minute tetrahedra. And, as a matter of fact, these crystals can be built up by the combined use of these two types, without any void between the particles; all the space is filled up, and, moreover the faces are (as is essential) parallel to the cleavage planes. The forms octahedron and tetrahedron are thus intimately related and must be regarded as different forms of the same thing.

The disposition of the bricks in the case of diamond is shown diagrammatically on sheet 22, where it will be noted that:

1°. — at every edge of a brick inside the crystal two octahedra and two tetrahedra meet.

2°. — each face of an octahedron inside the crystal is in contact with a face of a tetrahedron, and conversely.

That these two forms are intimately related is also shown (if further proof be needed) not only in the frequency with which tetrahedra are obtained in the manufacture of



STRUCTURE

OF THE

DIAMOND

SHEET 22

diamonds, but even more strikingly in the occurrence of rough diamonds of a tetrahedral crystallization. This crystallization, although rare (it is mentioned in no work on diamonds) occurs; the writer of the present thesis had a beautiful blue-white specimen of some ten carats in his hands some months ago and the tetrahedral character of the stone was very regular and definite; (the edges and faces of the crystal were rounded, as is usually the case with diamond crystals).

By this subdivision of a diamond crystal into exceedingly small octahedra and tetrahedra, all the phenomena of grinding can be very simply explained and the reason for the variable hardness follows easily.

When we want to study the variable hardness of the diamond or when we want to find why grinding proceeds in one particular direction and does not occur in another one, it is essential to have an accurate and plain picture of the above described structure of the diamond. For that purpose, a certain number of small octahedra and tetrahedra of a corresponding

size were made, by which models of the structure of the diamond could be built up. The various positions necessary are shown in the annexed photographs of these models.

Let us postulate, first, the following:

1°. — Grinding proceeds by the gradually tearing away of the constituent bricks.

2°. — The tearing away is caused by a succession of shocks given to the bricks (by the powder upon the grinding wheel).

3°. — The direction in which the shocks are given must be such that the bricks are torn away with ease or with little difficulty; i. e. the direction of grinding must be along the line of least resistance.

4°. — The direction of grinding must at the same time be such that the bricks present the greatest possible target to the powder particles, so that they have the maximum possible opportunity of suffering shocks.

Now it is obvious that the optimum direction will lie along an axis of symmetry of the facet ground; for in that case the particles will strike the bricks in a sym-

metrical direction, whereon both or either of the line of least resistance and the line of greatest action (i. e. where the targets are largest) may lie.

The above being admitted—they need no proof—let us now turn to the consideration of the various planes ground..

A. — Grinding of a face of the octahedron (= table of a 3-point or was).

Consider fig. 9, which shows us the model of that face, and suppose that the face ground be turned towards the spectator (as in the case when a facet is examined).

There are, in this case, two directions to be considered, the three axes of symmetry being identical.

1. — The grinding proceeds from right to left on the face as shown.

It will be clear that if the plane of grinding is co-incident with the plane of cleavage, the particles of powder are simply sliding on the face of the octahedron, and are striking none of the faces of the constituent

bricks; let us therefore incline slighly the facet ground, so that (say) the diamond touches the wheel on the right hand side.

Then (fig. 9, arrow 2), the particles when striking the stone force the constituent

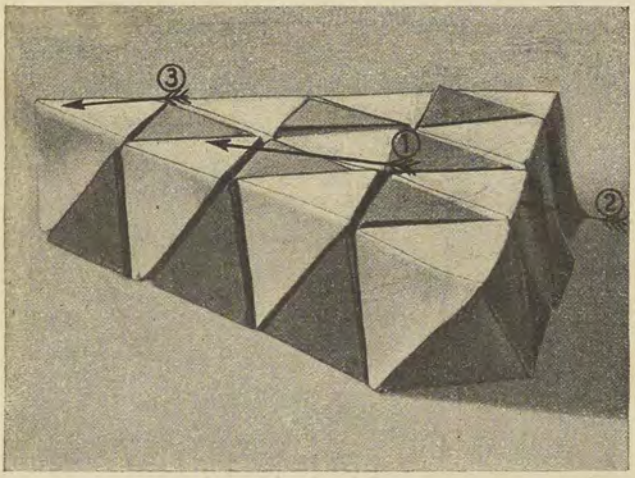


FIGURE 9

octahedra and tetrahedra into the stone. — No grinding occurs.

Let us therefore incline the diamond so that it touches the wheel on the left hand side (fig. 9 arrow 3). Then the first octahedron has its point nearest the grinding

wheel, so that the target fot the shocks is relatively small; but let us admit that it is struck and torn away and that the tetrahedron resting upon it is also removed.

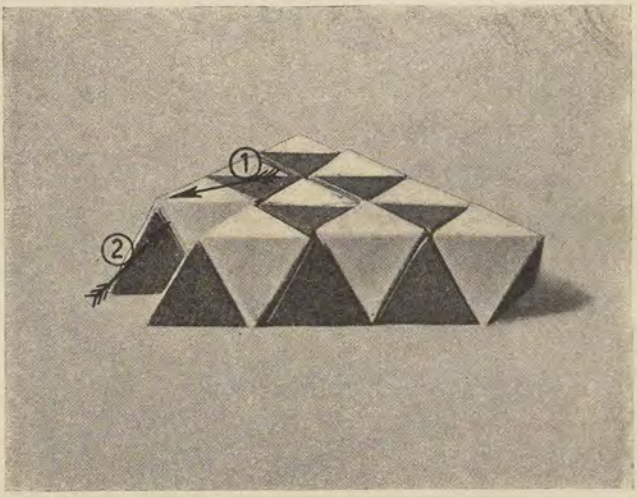


FIGURE 10

The position is then as shown in fig. 10. Let the next octahedra then be struck (arrow 1). It will be seen that they cannot be torn away, as they are wedged against the tetrahedra placed under them (arrow 2).

Grinding is impossible therefore along this direction.

Let us thus reverse the direction of grinding:

2. — The grinding proceeds from right to left on face as shown on Fig. 11.

As before, and for the same reasons, no

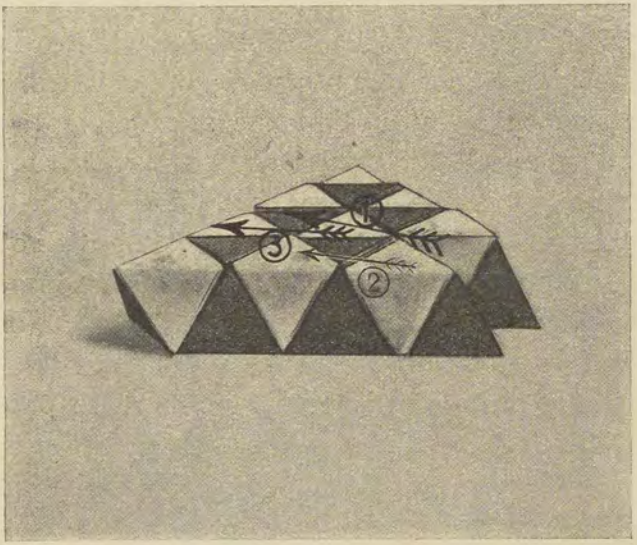


FIGURE 11

grinding will occur for directions corresponding to either arrows 1 or 2.

Let us therefore incline the diamond so that the face touches the wheel upon its broad (left-hand) side (arrow 3). We will

note first that the part of the bricks nearest the wheel is the broad side, an edge of the minute octahedra, so that the target presented to the powder particles is as large as possible (for that inclination to the plane of cleavage). Moreover, there is nothing to act like a wedge; the octahedra are torn away and at the same time the interspersed tetrahedra are removed: after the first row is gone the second is attacked and removed in the same away. It must not be forgotten here that the order of smallness of the bricks is much greater than that of particles of diamond powder, and that, also, the facet ground is resting upon these particles, so that there is a clearance between the cast-iron of the grinding wheel and the facet, in which the bricks are free to move.

This last direction (arrow 3) is thus the only direction of grinding. It will appear at once that if the angle of inclination be increased even slightly the effective area of the minute octahedra increases at a great rate, and the rate of grinding itself will increase correspondingly.

If we continue increasing the inclination, we come to a facet corresponding to the table of a 2-point.

B. — Grinding of a facet on the edge of an octahedron (= the table of a 2-point).

In this case there are four symmetrical

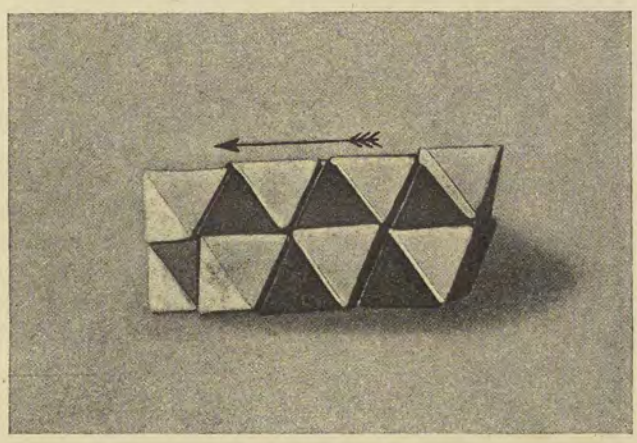


FIGURE 12

directions, two directions parallel to the edge and two directions perpendicular to the edge. As we are considering the ideal case, the directions in each pair are identical and there remain two cases to be considered.

1. — The direction of grinding is parallel to the edge (Fig. 12). The part

nearest the wheel is a long edge placed in a „streamline" direction. This edge is the lower edge of a long rhomboïdal prism which is not wedged in any way to the stone. If an exceedingly strong shock be

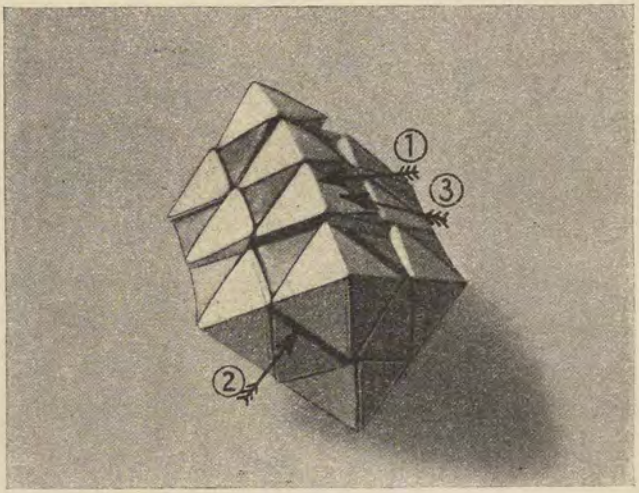


FIGURE 13

applied to the prism, it is conceivable that it might be removed altogether and at once. As it is, the adherence between the bricks is sufficient to prevent this, the more so that the area exposed to the shocks is very small. Even if we suppose the first prism gone,

then the same would apply to the subsequent layers or prisms: No grinding proceeds.

2. — The direction of grinding is perpendicular to the edge (Fig. 13).

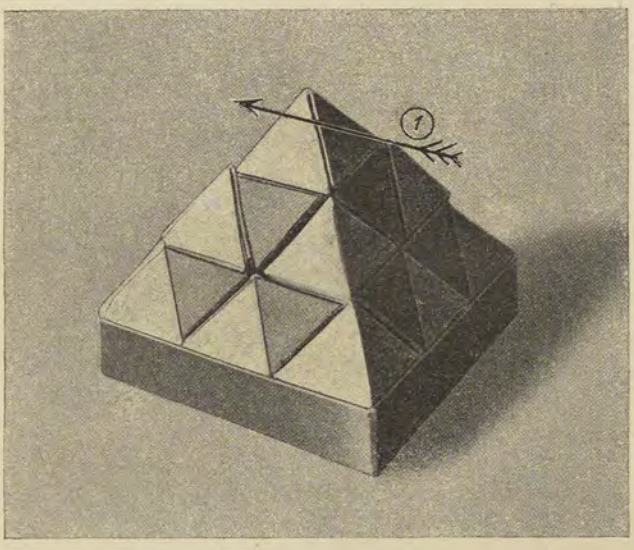


FIGURE 14

This is the position arrived at at the end of the study of plane A. The area forming target for the particles of diamond powder is very great, and the only resistance is the one

which the slope (marked by arrow 2) offers to the action of a shock (arrow 1) in the direction and position as shown on photograph.

It will be noted that if the inclination is decreased to position 3, the resistance is decreased, but the effect of the shock is decreased to a greater extent, so that the rate of grinding is smaller. If the inclination is increased, the line of action of the shock passes through the opposite face of the prism (arrow 2), so that the shock is ineffective and no grinding occurs even, after a small increase in inclination. The optimum position is thus the position of symmetry. (Compare whith sheet 23.)

C. — Grinding of a facet on the solid angle of an octahedron (= the table of a 4-point).

This case is perhaps the most interesting. — There are here 4 axes of symmetry, divided in two groups. The first pair passes from the centre of one face of the octahedron to the centre of the opposite face. The second passes from one edge through the apex to the other edge.

1. — The direction of grinding is from one face to the opposite face.

The position is as shown in Fig.14, the direction of grinding being given by arrow 1.

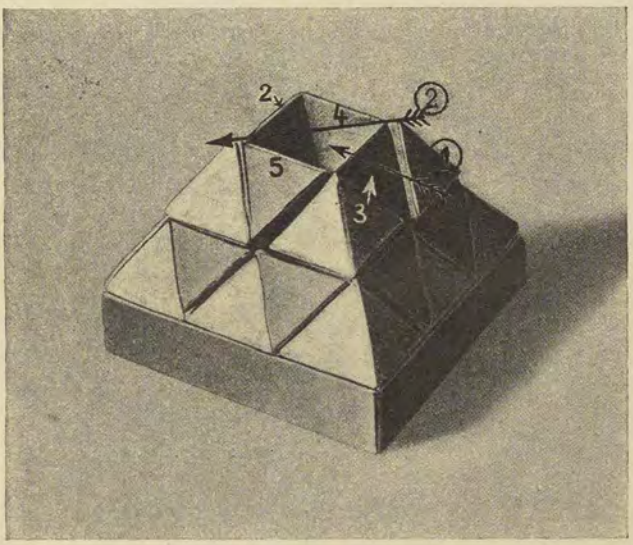


FIGURE 15

Let us admit that the apical octahedron is torn away by a shock. (Photograph 15.) Tetrahedra 2 and 3 will then also be removed by the grinding action; but tetrahedra 4 and 5 will oppose a big resistance to the tearing

away of further octahedra, which, at the same time, offer little surface to the action of the grinding wheel, so that the shocks cannot overcome the resistance; no grinding can occur.

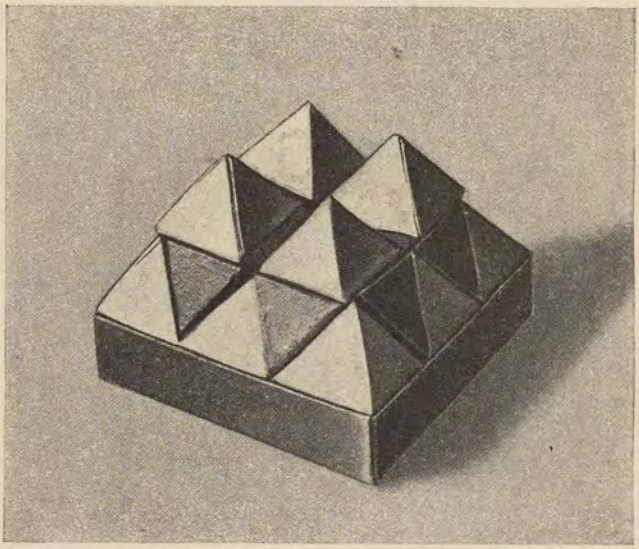


FIGURE 16

2. — The direction of grinding is parallel to the „corner to corner" axes.

As before, the apical octahedron leaves the stone relatively easily. The position is thus as shown in photograph 15; the

arrow 2 representing the direction of grinding; in this case, *each* of the tetrahedra is hit by the grinding powder, as they all offer a good target; they are thus thrown away (there being no resistance) and the second layer of octahedra is free to leave the stone upon the first shock, like the first octahedron left it, there being no resistance as all the tetrahedra are gone (Fig. 16).

Grinding will thus occur in a corner to corner direction, and will be slower than it was in the case of a table of a 2-point, as the target area is smaller.

If we compare the results of our above reasoning with what we found by experiment, we see that the theory explains easily not only why a particular direction is the direction of least hardness for a given area, or whether grinding does or does not occur in any given direction, but also the variation of minimum hardness from plane to plane.

The phenomena studied in the first part of the present thesis follow also very readily:

For the conclusions arrived at, were:

1° the rate of grinding is proportional to the linear speed of the grinding track.

2° the rate of the grinding is proportional to the intensity of pressure upon the facet ground (up to a limit of about 1500 pounds per square inch).

Now grinding is caused by shocks tearing away the constituent tetrahedra and octahedra of the diamond. The more shocks there are per minute the greater the rate of grinding will be. But the shocks are caused by the rapid translation of particles of diamond; the greater the rate of translation of the grinding track the greater the number of shocks per minute, and the greater the rate of grinding. As on a grinding wheel the pores are more or less uniformly distributed, the number of pores and powder particles per track varies as the diameter; hence, as was found experimentally:

1° The rate of grinding is proportional to the diameter of the grinding track.

2° The rate of grinding is proportional to the speed of the grinding wheel.

It follows that

3° the rate of grinding is proportional to the linear speed of the grinding track.

Now it is to be considered that the facet ground is resting on the particles of diamond powder passing under it; moreover, that these particles are not all the same height above the grinding wheel, so that at light pressure, only the ones standing out highest from the cast iron will hit the "bricks".

When we increase the pressure, the facet is forced nearer to the iron, and the number of particles hitting it is increased, so that the rate of grinding also increases. At a certain pressure it is forced so near to the wheel that, although the number of shocks increases, no further advantage is obtained from this fact, owing to the lack of clearance space between the facet and the wheel, which does no longer allow an easy tearing away of the minute tetrahedra and octahedra. This explains the phenomenon of critical pressure.

6. PRACTICAL APPLICATION OF THE RESULTS OBTAINED IN THE PRESENT RESEARCH

The practical importance of the results obtained need hardly be emphasised, nor is it difficult to see the direction of the improvements which are indicated for the diamond industry by these results.

The process of grinding, which is exceedingly long, can be considerably shortened by the following means:

1. — The increase of the linear velocity of the grinding track.
   This can be done in 2 ways:
   1° increase the diameter of the grinding wheel.
   2° increase the speed of rotation.

It would be difficult to increase the diameter more than two-fold, owing to the considerable weight and "unhandyness" of the grinding wheel even at that diameter. It would probably be better to keep the diameter one foot, as it is now, and to look for amelioration in the increase of the speed of rotation. That difficulty is to be expected in the provision of suitable bearings is to be seen from the beginning of the present thesis, but that difficulty can be — and was — overcome, a practical speed of 8500 R. P.M. having regularly been worked with, with a corresponding diminution of the time taken for grinding to one-quarter of its present value, other things being equal.

2. — This time was further shortened by the application of full loads i. e. of loads giving approximately the critical pressure. These loads are much heavier (three to four times) than the ones which are now usually put upon the tong and the rate of grinding was again considerably shortened. It is estimated that the speed of grinding can be increased ten to fifteenfold.

The great difficulty was the care that had to be taken not to grind too much off a particular facet. Both for this reason and because of the heavy loading, a special kind of dop and holder are indispensable. With the kind actually in use, it is impossible to load big or even medium stones to their critical pressure, owing to the copper wire joining the dop to the tong bending and making accurate work impossible. There must therefore be some other method of construction.

There must also be a kind of a stop guarding against there being ground too much of the facet. The special dop worked with during the experiments proved very satisfactory in both these respects.

Another point which the research emphasizes strikingly is the utmost importance of the correct direction of grinding being adopted. The whole difference between a fast grinder and a slow grinder is that the first knows by experience exactly how to place his stone upon the wheel, whereas the second proceeds more

or less haphazard: a good workman may grind more quickly at the normal speed than a bad one at treble speed.

PRACTICAL APPLICATION. It may be said here that as a first consequence of this research, the speed of rotation of the saws in the diamond sawing mills of the factory was trebled. This was found possible with the existing bearings, but for the best results the construction of the machines must be accurate and the design compact and well-proportioned.